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DRAFT

ENVIRONMENTAL TOBACCO SMOKE:
A COMPENDIUM OF TECHNICAL INFORMATION

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PREFACE

This compendium of technical information on Environmental Tobacco Smoke (ETS) is intended to be useful for a diverse audience, including: decision-makers such as labor and management officials concerned with workplace exposures, public health officials and corporate medical directors who are concerned with making health policy recommendations, educators, industrial hygienists and safety officers, ETS researchers, indoor air pollution investigators, and legislators who are considering legislation to restrict smoking in workplaces, restaurants, and public access buildings. There are ten chapters in this compilation, including health effects of active smoking in adults and passive smoking in children and adults, ETS exposure and dosimetry, comfort aspects, ventilation and ETS, public beliefs about the harm of ETS and attitudes toward controls, and effective workplace smoking policies, each of which is aimed at a somewhat different audience. Although not all chapters will appeal equally to such a varied group, it is hoped that the technical information in this document, written by experts in the field, will provide information necessary to allow the public, government agencies, and the building industry, to make well-informed choices regarding exposure to ETS.

This technical document represents a coordinated effort jointly sponsored by the Environmental Protection Agency (EPA), the National Cancer Institute (NCI), the Office on Smoking and Health (Centers for Disease Control), the National Heart, Lung, and Blood Institute, and the Office of Disease Prevention and Health Promotion (Department of Health and Human Services).

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TABLE OF CONTENTS

Chapter 1."Passive Smoking -- Beliefs, Attitudes, and Exposures in the United States"
Thomas E. Novotny.....6

Chapter 2. "Effects of Smoking on Smokers"
Donald Shopland 22

Chapter 3. "The Odor and Irritation of Environmental Tobacco Smoke"
William S. Cain 29

Chapter 4. "Environmental Tobacco Smoke and Cancer"
Jonathan M. Samet 40

Chapter 5. "Measuring Exposure to Environmental Tobacco Smoke"
Brian P. Leaderer 53

Chapter 6. "Environmental Concentrations of ETS"
John McCarthy, Elizabeth Miesner, and John D. Spengler 65

Chapter 7. "Exposure Assessment in Passive Smoking"
James L. Repace 79

Chapter 8. "Absorption of Smoke Constituents by Nonsmokers" Dietrich Hoffman, Klaus D. Brunnemann, and Nancy J. Haley.....95

Chapter 9. "Passive Smoking and Daycare"
Glen Bennett.....117

Chapter 10. "No Smoking Policies at the Worksite: A look at what companies are doing today"
Ruth Behrens 135

Chapter 10 Appendix: "Economic Justification for Worksite Smoking Policies"
Ruth Behrens 172

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INTRODUCTION

In 1986, the Surgeon General and the National Research Council, the latter under contract to EPA, examined the health effects of the breathing of Environmental Tobacco Smoke (ETS) by nonsmokers (also known as involuntary or passive smoking). They agreed that passive smoking caused lung cancer in nonsmoking adults, caused increased rates of respiratory infections in children, caused acute noxious effects in many nonsmokers, and was a major contributor to indoor air pollution. Subsequent to the publication of these documents, smoking restrictions began to proliferate. However, a number of diverse technical questions arose concerning public attitudes toward smoking restrictions, health and comfort effects, factors affecting exposure, measuring environmental concentrations of ETS, effects of ventilation on ETS and indoor air quality, nonsmokers' uptake of tobacco combustion products, and corporate experience in effective smoking policy, all comprise chapters in this compendium. In the interest of providing answers to this complex of questions, this technical compendium was commissioned. A brief summary of each chapter follows.

Chapter 1 discusses the results of national surveys of trends in public attitudes toward ETS and restrictions against smoking, particularly in the workplace. It is concluded that there is a trend toward restrictions on smoking in the workplace, accompanied by widespread public acceptance.

Chapter 2, in a series of simple bar charts, describes the effects of smoking on smokers, including cancers, cardiovascular disease, and respiratory diseases. It is graphically illustrated why cigarette smoking is now recognized as the Nation's single largest cause of premature death and disability.

Chapter 3 explores the effects of ventilation on the perception of odor and irritation from ETS in both nonsmokers and smokers, and shows that although most attempts to control ETS have relied on ventilation and air cleaning, they have limitations.

Chapter 4 discusses environmental tobacco smoke as a cause of lung cancer in nonsmokers, and discusses the conclusions of the World Health Organization, the National Research Council, and the U.S. Surgeon General on this issue.

Chapter 5 treats the methods of assessing nonsmoker's exposure to environmental tobacco smoke by atmospheric markers, and the measurement of these marker substances in indoor air.

Chapter 6 reviews studies of the concentrations of certain ETS constituents observed in homes, offices, and other locations by personal exposure monitors. It is concluded that ETS is the primary contaminant contributing to respirable particles and

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contributes substantially to other indoor contamininants such as benzene, carbon monoxide, and others.

Chapter 7 demonstrates how ventilation effects concentrations of tobacco smoke, and gives equations for the estimation of indoor environmental concentrations of respirable tar particles from ETS based on ventilation rates, number of smokers, and room size.

Chapter 8 provides a detailed treatment of the absorption and metabolism of tobacco combustion products by nonsmokers. It shows that absorption has been conclusively demonstrated by studies of nicotine and its metabolite, cotinine, in the body fuids of nonsmokers, and that such biomarkers represent a reliable specific method for assaying the level of uptake of ETS.

Chapter 9 analyzes the effects of passive smoking on young children and infants. The conclusion is reached that day care workers must be educated about the possible compounded effect of passive smoking and day care attendance on the increased risk of respiratory disease among infants and toddlers.

Chapter 10 examines features of corporate smoking policies in the workplace, with attention to benefits, incentives, employee and union involvement, and education. Case histories are discussed involving several major corporations, detailing problems encountered and successes. In an appendix an economic rationale for worksite smoking policies is given, with the conclusion that smokers burden employers with excess costs (in some cases 100% higher) related to their smoking relative to nonsmokers.

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CHAPTER 1

PASSIVE SMOKING--BELIEFS, ATTITUDES, AND EXPOSURES IN THE UNITED STATES

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Introduction

The relationship between public attitudes, policies, and exposure to certain health hazards is complex. With the release of the *18th Surgeon General's report on smoking and health, "The Health Consequences of Involuntary Smoking," (US DHHS 1987) public attention on the issue of Environmental Tobacco Smoke (ETS) was more strongly focused than ever before. For many years, however, pollsters, the tobacco industry, and the health promotion community have surveyed the public concerning attitudes toward ETS and toward restrictions against exposure to ETS. The Surgeon General's Report described data from several of these surveys as well as results from evaluations of worksite and local policy changes. Additional detailed data on public beliefs and attitudes toward smoking in general are found in the 1989 Surgeon General's Report: Reducing the Health Consequences of Smoking -- 25 years of Progress. Recently, surveys have also included both questions on beliefs about the harmfulness of ETS to the nonsmoker and on respondents' reported exposure to ETS. In addition to such individual exposure data, surveys of worksites and of personnel managers have provided information about restrictions on ETS exposure to workers. Because changes in public attitudes toward ETS usually precede laws or policies regarding ETS exposure (US DHHS 1987), an examination of trends in these data over time is useful. This section will consider several different nationally-based data sets andsummarize the most important findings from them.

Surveys of Public Beliefs, Attitudes, and Exposures

The surveys reported in this section are summarized in Table 1.

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These surveys may report discrepant results. Most discrepancies can be explained by the differences in methodology, especially in the ways that questions are worded. Nonetheless, comparisons between surveys are useful.

The only Roper Survey commissioned by the Tobacco institute available to the public was done in 1978. The narrative from this study included data from 1974 and 1976 also. Additional surveys on public attitudes have been performed by Roper or other agencies for the industry, but many of these are not available. A recent Tobacco Institute-sponsored survey of attitudes toward government policies conducted by Hamilton, Frederick, and Schneider has been made available and is reported. The 1974-1978 Roper surveys permit comparisons of data collected for the tobacco industry with similar data collected in the 1970s by the Office on Smoking and Health (formerly known as the National Clearinghouse on Smoking and Health). Additional national surveys of public attitudes and beliefs were performed in the 1980's by the Gallup Organization and the Louis Harris Co.

National surveys of worksites were also carried out in the 1980's in conjunction with increasing restrictions and laws against smoking in public places throughout the United States (US DHHS 1987). These surveys, which indicate the degree to which workers may be protected from ETS exposure, permit comparisons with exposures reported by individual respondents in the 1986 Adult Use of Tobacco Survey (AUTS) of the Office on Smoking and Health. In addition, the 1987 Gallup survey of attitudes toward smoking in restaurants described public opinion about exposure in an additional, policy-relevant, nonworksite setting. The 1987 National Health Interview Survey of Cancer Epidemiology and Control collected information about respondents' actions in response to ETS exposure.

Data Sources and Methodology

Tobacco Industry Surveys

Roper Surveys

The Roper Organization conducted six biennial national opinion surveys for The Tobacco Institute between 1966 and 1978. The *1974, 1976, and 1978 surveys focused on the passive smoking/non-smoker's rights issue (Roper 1978), whereas all six surveys dealt with public attitudes towards the smoking and health issue, towards the tobacco industry itself, and towards *goverriment regulation of tobacco. The surveys were telephone-based, but information about the exact methodology, sample sizes, and response rates is unavailable.

In December 1988, the Tobacco Institute sponsored a National adult

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telephone survey of 1500 persons which was conducted by Hamilton, Frederick, and Schneiders (Hamilton, Frederick and Schneiders, 1989). This survey asked about various public policy issues and was to measure levels of support on governmental policy on smoking. The respondents were asked what they thought about restrictions on smoking in restaurants and worksites. The results were not reported by smoking status of the respondents, but 401 (27%) of the respondents were smokers. The response rates were not reported.

Other Public Opinion Surveys

Gallup Surveys

Gallup Poll results have been published monthly by the Gallup Organization since 1965. Surveys are either personal interviews or by telephone, with a population-based sample of at least 1000 adults, $\geq$ 18 years of age. The sampling error for overall responses is reported to be no more than $\pm 3\%$ (Gallup Report 1987). In addition, Gallup surveys may be commissioned by a variety of organizations. The surveys reported here were commissioned by the American Lung Association (1983, 1985, 1987, and 1989) and The American Cancer Society (1988) to study both the prevalence of smoking and public opinions regarding smoking issues. An additional Gallup Survey was commissioned by the National Restaurant Association (1987) to obtain public opinion on smoking in restaurants. The 1989 Gallup Survey sponsored by the American Lung Association did not ask respondents about their smoking status.

Harris Poll

Louis Harris and Associates have performed eight national surveys between 1974 and 1987 using probability samples of adults aged 18 and older. These surveys were conducted on behalf of various organizations, including Prevention magazine and Pacific Mutual Life Insurance Co., to ascertain health practices in Americans. In 1987, 1250 persons were also asked about regulating smoking in public places.

Government Sponsored Surveys

Adult Use of Tobacco Surveys (AUTS)

The Office on Smoking and Health (formerly, National Clearing House on Smoking and Health) commissioned surveys of adult smoking behavior, attitudes, and beliefs beginning in 1964. These surveys oversampled smokers, but final results were weighted to represent the United States resident population aged 21 years and older (1964, 1966, 1970, 1975). The 1986 AUS oversampled smokers and also collected data from persons aged 17 and older. The final data in this survey were weighted to reflect the educational, regional,

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racial, and age distribution of the U.S. population based on the 1986 Current Population Survey of the U.S. Bureau of the Census. More detailed information on attitudes, beliefs, and exposure regarding ETS was collected in this survey.

National Health Interview Survey

The National Health Interview Survey of Cancer Epidemiology and Control (NHIS-CEC) collected data in-person from 22,000 adults ≥18 years of age in households throughout the United States. The data are weighted to reflect the entire U.S. population, and the overall response rate for NHIS-CEC was 82%. Respondents were asked about the harmfulness of ETS and about attitudes toward passive smoking. These included perceived annoyance and whether smoking should occur inside public places. Nonsmokers were asked about their actions in response to smokers' lighting up in their presence.

Other Surveys

Worksite Surveys

Several surveys of worksites and businesses have been carried out in the last several years. These are described in detail in The 1986 and 1989 Surgeon General's Reports (U.S. DHHS 1987, 1989). The Bureau of National Affairs and the American Society for Personnel Administration (ASPA) conducted a mail-in questionnaire survey of ASPA members. Six hundred twenty-three respondents reported on activities related to smoking in the workplace. The response rate was 54%. A similar survey had been carried out in 1986 on 662 businesses, and results on the presence or absence of restrictions were comparable.

In 1988, the Office of Health Promotion and Disease Prevention (OHPDP) of the United States Public Health Service reported on worksite health promotion activities, including smoking control. The survey was carried out in 1985 on a sample drawn from the Dun and Bradstreet list of businesses. Using a telephone interview, 320 worksites with 50-90 employees and 1,038 worksites with 100 or more employees, drawn from a probability sample based on geographic region, size of firm, and industry type, were surveyed. Questions about smoking restrictions were included.

In December 1984, the American Board of Family Practice (ABFP) sponsored a National telephone survey of 1007 adults ≥18 years of age and of 303 Family Physicians conducted by Research and Forecasts, Incorporated. The results were published in a report entitled, Rights and Responsibilities: Healthcare Options. Questions were asked regarding beliefs about the harmfulness of ETS, the rights of smokers and non-smokers, and whether smoking restrictions are effective in stopping or discouraging smoking. The final sample response rates were 41% for the general public

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and 37% for physicians. Data for the general public portion of this survey were weighted to reflect the 1985 U.S. Census for 1985. The physicians surveyed represented a random sample of U.S. Family Physicians.

Results of Surveys

Perceived Harmfulness of Environmental Tobacco Smoke

Although the questions asked on the various surveys regarding ETS may differ somewhat, comparisons between surveys are still useful. The Roper Surveys asked questions regarding harm and annoyance caused by ETS. All AUTS surveys asked about annoyance caused by ETS, but only the 1986 AUTS asked if respondents believed that ETS was harmful to the nonsmoker. The 1983 and 1988 Gallup Surveys asked if respondents believed that smoking is hazardous to the health of nonsmokers. The 1978 Roper Survey and both the 1986 AUTS and 1988 Gallup surveys provide interesting information on the change in public beliefs about the harmfulness of ETS to the nonsmoker over the last several years. The 1985 ABFP Survey asked both adults and physicians if they believed nonsmokers are harmed by breathing in the smoke of others in the same room.

Table 3 shows the responses to survey questions regarding harmfulness caused by ETS. Between 1974 and 1986, the percentage of smokers who believed that ETS is harmful to the health of the nonsmoker more than doubled. In 1974, most nonsmokers believed that ETS is harmful to health in general, and the percentage of those who held this belief increased substantially to almost 90% in 1989 and 1988. Overall, the percentage of persons who believe ETS is harmful to health increased from 46% in 1974 to 81% in 1988. In an additional question on the 1986 AUS, 69% of non-smokers (62% of former smokers and 74% of never smokers) felt that ETS is harmful to their own personal health. The resluts of the 1989 Gallup poll suggest that there is even stronger belief in the harm of ETS to pregnant women and children. These data suggest that there has been a major change in the perception of ETS as a health hazard over the last decade.

Annoyance Caused by Environmental Tobacco Smoke

The AUTS surveys show an increasing trend in the percentage of respondents who are annoyed by ETS, (from 46% to 69% of all respondents between 1964 and 1987) (Table 3a). Data regarding annoyance to ETS from Roper Surveys other than the 1978 survey are not available. However, the results of the 1978 Roper Survey report that 60% of nonsmokers and 5% of smokers were annoyed by the smoke of others. These data suggest that increasingly fewer Americans are tolerant of ETS exposure. The results of the 1987 NHIS-CEC indicate increased annoyance to ETS as well (Table 3a).

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Fewer current smokers reported annoyance than on the 1986 AUTS (34% vs 42%), but this difference may be in part due to the different methodologies and sampling frames used in these two surveys. A greater percentage of never smokers reported annoyance in 1987 than in 1986 (88% vs 83%), but the overall response was exactly the same (69% annoyed) on the two surveys. The NHIS-CEC also collected information about what non-smokers did in response to exposure to ETS. About half of respondents moved away from the exposure source, 40% did nothing, 3% did something else, and only 4% asked the person not to smoke. Despite high positive responses to perceived harm caused by and annoyance to ETS, most non-smokers remain rather passive in their behavior toward exposure sources (Davis, in press).

Limiting or Banning Smoking in Public Places

Roper Surveys

The Roper Surveys began questioning the public about laws to prohibit smoking or to segregate smokers in 1974. The percentage of respondents favoring segregation in a variety of public places is shown in Table 4. The majority of respondents felt that smokers should at least be segregated in all the public places cited. After asking about segregation of smokers and nonsmokers, respondents were asked if amoking should be banned outright in selected public places. The percentage of respondents favoring bans is shown in Table 5. The majority of respondents favored smoking bans in retail stores, physicians' or dentists' waiting rooms, and elevators. The Roper Survey was careful to ask about segregating smokers before asking about entirely banning smoking in public places. The narrative pointed out that after recognizing the option to segregate smokers, respondents were probably less likely to be in favor of a total ban (Roper 1978).

The two most important reasons given by Roper Survey respondents prior to 1978 as to why smoking should be restricted always had to do with dangers to others, specifically, cigarette smoking as a fire hazard and ETS as a health hazard to nonsmokers. In 1978, the "health of non-smokers is harmed by other people smoking in their presence" became the chief reason given by respondents (33%) in favor of public laws against smoking.

Gallup Surveys and Polls

In 1983, 1985, 1987, and 1989, the Gallup Poll telephone surveys conducted on behalf of the American Lung Association (ALA) asked if smokers should refrain from smoking in the presence of nonsmokers. Table 6 shows the results of these surveys. Overall,

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the percentage of respondents to these surveys agreeing that smokers should not smoke in the presence of nonsmokers has increased between 1983 and 1989. This trend holds true for both smokers and nonsmokers in 1987 more than three-quarters of adults, including 64% of current smokers, 76% of former smokers, and 86% of nonsmokers, held this opinion. The 1989 survey did not differentiate between smokers and nonsmokers. The Gallup Organization also surveyed U.S. residents as to their opinion regarding where smoking should be restricted or banned. With regard to smoking in certain hotels, motels, and restaurants, the majority of respondents in both 1983, 1987, and 1989 felt that certain areas should be set aside for smoking (Table 7a). Bans were less favored, especially by current smokers.

In addition to the 1983 and 1987 surveys, Gallup respondents were asked if companies should have a policy on smoking at work in 1985. The results of these surveys are also shown in Table 7. By 1985, almost 90% of all respondents, including 80% of smokers and 89% of nonsmokers, felt that smoking should be assigned to certain areas of the worksite or that it should be totally banned at work.

In 1987, the monthly Gallup Polls (not commissioned by the ALA) asked if respondents favored or opposed a complete ban on smoking in all public places. The results of this poll are much more strongly in favor of total bans on smoking in public places. Overall, 55% of Americans favor a ban (43% oppose and 2% have no opinion). Stratified by smoking status, 69% of nonsmokers and 25% of smokers favor such a ban. These results contrast sharply with the Roper results of almost a decade ago and are even more impressive than the ALA sponsored surveys in the same year.

In the Gallup Survey conducted for the National Restaurant Association in 1987, 61% of adults reported that they preferred to sit in non-smoking sections in restaurants. These included 20% of smokers, 65% of former smokers, and 83% of never smokers. (Mills 1987) These results are similar to the AUTS results on non-smoking section preferences described below. However, an increasing trend toward favoring the prohibition of smoking in public places is evident. By 1989, the percentage of respondents favoring prohibition of smoking was 12% for hotels and motels, 23 % for restaurants, and 21% for worksites.

NHIS-CEC

The 1987 NHIS-CEC asked a slightly different question, which restricted the respondent to consider indoor public places. The percentage of all respondents, especially former smokers, agreeing that smoking should not be done inside public places, was higher on this survey than on the 1987 Gallup survey (Table 6b). The Gallup question applied to a general statement about refraining from smoking in the presence of nonsmokers.

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Hamilton, Frederick, and Schneiders Survey

Interestingly, the Tobacco Institute-sponsored survey (Table 5b) showed even stronger responses for restaurant and worksite restrictions in 1988. For each of these sites, the question referred to the "current policy" as a choice; for restaurants, the choice was up to customers to select smoking vs. nonsmoking sections, and for worksites, the choice was up to employers and employees to decide on worksite policies. Fewer respondents in this survey favored no restrictions on smoking than in the American Lung Association survey (restaurants 2% vs 8%, worksites 3% vs 10%).

Adult Use of Tobacco Surveys

Between 1964 and 1975, the percentage of respondents favoring restrictions on smoking in public places increased from 52% to 70% (Strongly agree and mildly agree) (Table 8). The question asked in 1986 was quite different from the questions asked in the earlier surveys, but the 1986 responses are also shown in Table 8. Between 1964 and 1975, AUTS respondents favoring increased restrictions increased 18 percentage points, from 52% to 70% overall. About half of respondents in 1986 felt that restrictions against smoking were adequate, perhaps because many more restrictions were in place by 1986.

In 1966 and 1975, respondents were also asked if employers have a right to regulate smoking in their places of business. In 1966, 92% felt that the "employer has a right to tell a person when or where he can smoke while on the job," whereas in 1975, 78% felt that "management should have the right to prohibit smoking in their places of business." These are somewhat different questions; the first has to do with management's right to regulate employees, and the second has to do with management's right to regulate customers, visitors, and employees.

Harris Poll

In 1987, respondents to the Harris Poll, performed on behalf of Prevention magazine, were asked if they think that laws should prohibit smoking in public places, should these laws require separate smoking and nonsmoking sections, or should smoking in public places not be regulated by law. Among all respondents, 23% felt that laws should prohibit smoking in public places, 61% felt that laws should require separate smoking and nonsmoking sections, and only 13% felt that laws should not regulate smoking in public places at all (3% were unsure). Again, more than 80% of respondents, smoking and nonsmoking, **favored** restrictions against smoking in public places.

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Public Opinion on Restrictions After Enactment

Few evaluations of the acceptability of laws banning smoking in public places have been performed. New York City enacted a ban on smoking in most public places, including restaurants, in April, 1988. Three months after the ban took effect, a telephone poll of 676 randomly sampled New Yorkers (New York Times/WCBS-TV poll) revealed that 73% of respondents overall approved of the law, including 84% of nonsmokers and 43% of smokers (New York Times, 7/5/88).

The 1986 AUTS asked respondents if they would select nonsmoking sections if given a choice. Overall, 61% choose nonsmoking seating in airplanes, restaurants, and other public places. This includes 82% of never smokers, 69% of former smokers, and even 14% of current smokers. These data suggest a high degree of acceptability for smoking restrictions (CDC 1988).

Finally, A Clean-Air Ordinance took effect in March 1987 in Cambridge, Massachusetts, and was evaluated after three months. This evaluation revealed that 78% of Cambridge residents favored the restriction, including 41% of smokers and 90% of nonsmokers (Rigotti 1988).

Exposure to ETS

Many studies have been performed demonstrating the biochemically measurable exposure of nonsmokers to ETS (US DHHS 1987). However, only the 1986 AUTS has asked a nationally representative sample of residents about exposure to ETS. A subsample of 8,600 working respondents from the AUS was analyzed as to reported exposure at the worksite and as to reported policies that restrict smoking at their worksites. Table 9 shows the percentage of working respondents reporting exposure to ETS according to reported worksite smoking restrictions in place. Fifty-three percent of respondents who worked in environments with restrictive smoking policies still reported exposure to ETS. Of these, 11% reported that their worksite is "very smoky." Even among the 2.5% of respondents reporting a total ban on smoking in the workplace, 21% still reported being at least somewhat exposed to ETS at work. These data suggest that worksite restrictions decrease but do not eliminate reported exposure to ETS at the worksite.

Worksite Surveys

In 1987, a random sample of the members of the American Society for Personnel Administration (ASPA) reported that their worksites had restrictive smoking policies. In 1986, a similar survey showed that

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the percentage reporting restrictive policies was only 36% (BNA 1987). The 1986 figure was nearly the same as the percentage of individual workers reporting such policies in the 1986 AUTS.

Among respondents to the 1985 ODPHP Worksite Survey, 35.6% of worksites reported offering amoking control activities, including classes, information, special events, or contests. Of these companies, 76.5% also had formal smoking policies (not separated by restriction or prohibition). In addition to frequently cited benefits such as improved employee morale, improved employee health, etc., respondents reported cleaner air and work environments, fewer smokers in the workforce, and fewer complaints from nonsmokers (USPHS1988).

Perceived Future Effect of Restrictive Smoking Policies

Research and Forecasts, Incorporated

Many of the surveys on public opinion cited above asked respondents about their beliefs and attitudes toward passive smoke. Others asked about whether the respondents favored restrictions on smoking in public places. The National Survey of Healthcare Opinions sponsored by the American Board of Family Practice (ABFP) in 1985 asked adults and Family Physicians if restrictions on smoking in medical facilities or on the job would be effective in stopping or discouraging smoking. The survey also asked if legally banning all tobacco use everywhere would be effective. Among the general public, 57% felt that restrictions in medical facilities would be effective, 40% felt that restrictions by employers against smoking on the job would be effective, and 21% felt that legally banning the use of all tobacco would be effective. Among physicians, 83% felt that such restrictions would be effective in health care facilities, 67%. felt that restrictions would be effective on the job, and 17% felt that totally banning the use of all tobacco products would be effective. These responses should be differentiated from those in other surveys that ask about support for restrictive smoking policies.

The ABFP survey tried to ascertain if policies were an effective intervention for smokers to refrain from using tobacco, whereas the Gallup surveys tried to ascertain what people want in terms of protecting the nonsmoker from exposure to ETS. Few studies have actually been able to assess the effect of restrictive smoking policies on smokers' behavior, but studies from individual worksites show decreased numbers of cigarettes smoked per day without a change in the prevalence of smoking (Peterson et al., 1987, Rosenstock et al., 1986).

Summary and Conclusions

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These data indicate an important shift in public beliefs and attitudes toward ETS over the last decade or more. While the vast majority of U.S. citizens have recognized over the years that cigarette smoking is directly harmful to the health of smokers (89% of males and 90.9% of females in 1975 [AUTS 1975]; 92% of males and 91.8% of females in 1986 [AUTS 1986), the percentage of survey respondents who believe that ETS is also harmful to the health of nonsmokers has increased dramatically (46% overall in 1974 [Roper 1978] to 81% overall in 1986 [AUTS 1986, Gallup 1988]). Even more Americans agree that ETS is harmful to vulnerable populations such as pregnant women and children.

Many laws and local ordinances were put into place during the last decade, also, and the process of these legislative activities undoubtedly increased public awareness of ETS issues. The National Academy of Sciences Report and the Surgeon General's Report on Involuntary Smoking were released in late 1986. However, very little of the change in belief about ETS harmfulness can be attributed to the publication of these reports, even though they received enormous media attention; most of the 1986 AUS had been completed by late 1986. Therefore, the increase in reported beliefs about ETS likely reflects a growing and sustained awareness among U.S. residents about ETS as a health hazard rather than merely a public response to the highly visible Surgeon General's Report. This report may have convinced more persons abut the harmful effects of ETS, as evidenced by the results of the 1989 Gallup Survey.

The somewhat discrepant results on attitudes toward laws regarding restricting smoking in public places found in the 1986 AUTS and the 1988 Harris Poll may be explained by the differences in the way the question was asked in this survey. Many laws were put into place by 1986, and respondents may have felt less concerned about increasing regulations than they did in earlier surveys, before these laws were in effect. Where these laws have been evaluated, there appears to be widespread acceptance of them. Some studies have implied that such laws have a beneficial effect on smoking behavior. (Lewit,1988)

There appears to be a trend towards limiting smoking in workplaces. It is unclear as to whether workplace laws and regulations against ETS or simply the *concern for the health of nonsmokers is the stimulus for this trend. The 1986 AUTS results, which show that even with a total ban on smoking in the workplace some workers are exposed to ETS, suggests that there may be incomplete enforcement of restrictions. In worksites with segregation of smokers and nonsmokers, exposure to ETS may result from the lack of efficacy of separating smokers and nonsmokers within the same airspace. The 1986 Surgeon General's Report concluded that this level of restriction was inadequate to protect the nonsmoker from ETS (US DHHS *1987). The 1990 Health Objectives for the Nation, which were

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adopted by the Public Health Service, recommend that all 50 states have laws by 1990 that both prohibit smoking in enclosed public places and require separate smoking areas in the workplace and in dining establishments (Public Health Service 1980).

As of the publication date of the 1989 Report of the Surgeon General (January, 1989), 31 State had laws restricting smoking in public worksites, 13 had laws restricting smoking in private worksites, and 26 had laws restricting smoking in restaurants (US DHHS 1989). It is important to continue to assess public knowledge and beliefs regarding tobacco use as new information becomes available. These survey results assist public health providers in measuring the success of policies to control health hazards such as ETS. In addition, these data emphasize the change in the social milieu surrounding tobacco use. As public attitudes shift away from the social acceptability of smoking, it may be more and more important both for smokers to quit and for potential smokers to avoid smoking. It may also be easier for policy-makers to address tobacco issues more directly if they understand the nature of and the changes in public opinions expressed through these surveys.

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Table 1. Surveys With Information on Beliefs, Attitudes, and Exposures to Environmental Tobacco Smoke

Survey	Year	Sponsor
Adult Use of Tobacco	1964,1966,1970 1975,1986	Office on Smoking and Health
Research and Forecasts	1985	American Academy of Family Physicians
Gallup Survey	1983,1985,1987	American Lung Association
Gallup Survey	1987	National Restaurant Association
Gallup Survey	1988	American Cancer Society
Harris Poll	1987	Prevention Magazine
Roper Organization	1974,1976,1978	Tobacco Institute
Hamilton, Frederick and Schneiders	1988	Tobacco Institute

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Table 2. Beliefs About Harmfulness Caused by

Environmental Tobacco Smoke (% of Respondents)

by Smoking Status

ETS Harmful to Non-smokers

Survey	Smoking Status				Total
	Current Smokers	Former Smokers	Nonsmokers	Never Smokers	
Roper 1974	30		57		46
Roper 1976	38		61		52
Roper 1978	40		69		58
Gallup 1983	64	80	84		
Research and Forecasts 1985					77 (Physicians-87)
AUTS 1986	69	82	85	87	81
NHIS-CEC 1987	67	84		89	82
Gallup 1988	64	86		89	81
Gallup 1989					86% (To Adults) 88% (To Pregnant Women) 89% (To Children)

Source: Roper Organization 1978; Gallup Surveys 1983, 1988; Adult Use of Tobacco Survey 1986, Research and Forecasts 1985

Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

Table 3.a Annoyance Caused by
Environmental Tobacco Smoke (% of Respondents)
by Smoking Status

Annoyed by ETS

Survey	Smoking Status				
	Current Smokers	Former Smokers	Nonsmokers	Never Smokers	Total
Roper 1978	5		60		
AUTS 1964	20	49	64	69	46
AUTS 1966	26	52		70	48
AUTS 1970	34	63	73	78	59
AUTS 1975	35	72	79	79	63
ROPER 1978	5		60		
AUTS 1986	42	73	80	83	69
NHIS-CEC 1987	34	75		88	69

Source: Adult Use of Tobacco Surveys 1964, 1966, 1970, 1975, 1986; Roper Organization 1978, NHIS-CEC 1987.

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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

Table 3.b Reactions to Secondhand Smoke in Public Places, 1987*

	Former Smokers	Never Smokers	Total
Ask Person Not to Smoke	4	5	4
Move Away	52	46	52
Do Nothing	40	47	40
Something else	3	3	3

*Not asked of current smokers

Source: 1987 NHIS-CEC

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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

Table 4. Public Opinion (% of Respondents) on Separation of Smokers and Nonsmokers in Selected Public Places, 1978

	Smoking should be permitted	
	In separate sections %	Anywhere %
In trains, airplanes and buses	91	7
In theaters	83	11
In eating places	73	25
At indoor sporting events	73	22
At public meetings	67	28
In train, plane, bus stations	62	34
In work places or offices	61	34
In barber or beauty shops	53	42

Source: Roper Organization 1978

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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

Table 5.a Public Opinion (% of Respondents)
on Banning Smoking in Selected Public Places, 1978

	Should smoking be	
	Banned	Not banned
	%	%
In elevators	86	12
In doctors' or dentists' waiting rooms	69	27
In retail stores	55	41
In theaters	44	47
At indoor sporting events	34	57
At public meetings	32	58
In city, state or federal buildings	32	63
In taxis	32	64
In trains, planes, buses	26	65
In eating places	23	68
In barber or beauty shops	21	70
In work places or offices	17	73
In train, plane, bus stations	16	75

Source: Roper Organization 1978

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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

Table 5.b Public Opinion (% of Respondents)
on Prohibiting Smoking or Retaining Current Policies
in Selected Public Places, 1988

	Current Policy	Prohibit all Smoking	No Restriction
In Restaurants	74	24	2
In Worksites	76	20	3

Source: Hamilton, Frederick, and Schneiders 1988

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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

Table 6.a Should Smokers Refrain from Smoking in the Presence of Nonsmokers? (% of Respondents) by Cigarette Smoking Status, 1983, 1985, 1987, and 1989

Smoking Status	Agree				Disagree				Don't Know			
Survey Year	'83	'85	'87	'89	'83	'85	'87	'89	'83	'85	'87	'89
Current Smokers	55	62	64		39	37	31		6	1	5	
Former Smokers	70	78	76		22	22	19		8	0	5	
Nonsmokers	82	85	86		14	15	10		4	*	4	
All Respondents	69	75	77	82	25	24	19	15	6	1	4	2

*Less than 0.5%

Source: Gallup Surveys 1983, 1985, 1987, 1989

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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

Table 6b. If People Want to Smoke, They Should Not Do So Inside Public Places Where it Might Disturb Others. (1987)

	Agree	Disagree	No Opinion
Current Smokers	67	22	9
Former Smokers	80	10	8
Never Smokers	89	5	5
All Respondents	81	11	7

Source: NHIS-CEC 1987

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Table 7.a Opinions Regarding Smoking in Selected Public Places and Worksites, (% of respondents) by Smoking Status, 1983, 1985, 1987, 1989

Hotels and Motels

	Set Aside Certain Areas			Totally Ban Smoking			No Restrictions			Don't Know		
	'83	'87	'89	'83	'87	'89	'83	'87	'89	'83	'87	'89
Current Smokers	49	61		7	6		42	30		2	3	
Former Smokers	54	72		13	9		27	16		6	3	
Nonsmokers	60	68		15	14		20	15		5	3	
All Respondents	54	67	63	12	10	12	30	20	18	4	3	6

Restaurants

	Set Aside Certain Areas			Totally Ban Smoking			No Restrictions			Don't Know		
	'83	'87	'89	'83	'87	'89	'83	'87	'89	'83	'87	'89
Current Smokers	74	79		12	7		13	13		1	1	
Former Smokers	71	74		19	19		9	6		1	1	
Nonsmokers	65	71		26	23		7	5		2	1	
All Respondents	69	74	66	19	17	23	10	8	8	2	1	3

Worksites

	Set Aside Certain Areas				Totally Ban Smoking				No Restrictions				Don't Know			
	'83	'85	'87	'89	'83	'85	'87	'89	'83	'85	'87	'89	'83	'85	'87	'89
Current Smokers	64	76	72		11	4	8		21	19	18		4	1	2	
Former Smokers	68	80	73		14	12	16		14	6	8		4	2	3	
Nonsmokers	63	80	67		24	9	23		9	10	8		4	1	2	
All Respondents	64	79	70	65	17	8	17	21	15	12	11	10	4	1	2	4

Source: Gallup Surveys 1983, 1985, 1987, 1989

Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

Table 8. Restrictions on Smoking in Public Places
(% of respondents favoring increase)
by Smoking Status, 1964, 1966, 1970, 1975, and 1986

Smoking Status	1964	1966	1970	1975	1986*
Current Smokers	34	35	42	51	23
Former Smokers	56	58	61	77	53
Never Smokers	68	67	68	82	63
All Respondents	52	52	57	70	50

*The question for the first four surveys read "The smoking of cigarettes should be allowed in fewer places than it is now." The question in 1986 read "There are already enough restrictions on where people can smoke."

Source: Adult Use of Tobacco Surveys 1964, 1966, 1970, 1975, and 1986.

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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

Table 9. Reported Worksite Smoking Policies and Worksite Exposure to Environmental Tobacco Smoke (% of Respondents), 1986

Worksite Policy	% Reporting Policy	% Reporting Exposure to ETS
Not Restricted	55.4	64.8
Restrictive	42.1	53.2
Total Ban	2.5	21.1

Source: Adult Use of Tobacco Survey 1986

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TABLES AND FIGURES, CHAPTER 1

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CHAPTER 2

EFFECTS OF SMOKING ON SMOKERS

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Use of tobacco in the United States predates the arrival of Columbus and the early settlers. In the early part of the 16th century, soon after the introduction of tobacco into Spain and England by explorers returning from the New World, controversy developed from differing opinions as to the effects of human use of the leaf and products derived from it by combustion of other means. Pipe smoking, chewing, and snuffing (also dipping) of tobacco were praised for pleasurable and even reputed medicinal actions. Attempts aimed at controlling its use throughout the centuries proved useless--particularly when its control was based on moral and religious grounds.

Even though tobacco use has been a part of the American culture for the better part of four centuries, the use of cigarettes has a much shorter history than that of other forms of tobacco consumed per adult, over 6 pounds, was in the form of chewing tobacco (4.1 lb), pipe tobacco (1.63 lb.), and snuff (0.32 lb.). Cigars and cigarettes accounted for the remaining pound of tobacco consumes, with cigars accounting for the larger proportion.

As a nation, the U.S. consumed approximately 2.5 billion cigarettes annually or only about 54 cigarettes annually per person 18 years of age and older in 1900 (Figure 1). This pattern of tobacco use changed radically soon after 1910 with the introduction of the blended cigarette--demand accelerated as cigarette advertising and promotion became more aggressive.

Male tobacco users changed from other forms of tobacco to cigarettes in a relatively short time period. By the end of the First World War, a majority of males had become cigarette smokers. In contrast, women did not take up cigarette smoking in large numbers until nearly 25 years later. Women, however, had never used other tobacco products (except for snuff) and few of the older age cohorts of women had ever been smokers. Thus compared to men who switched from other forms of tobacco, women

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once they adopted tobacco use, were almost exclusively cigarette smokers.

It is somewhat ironic that one of the reasons for the rapid switch from smokeless tobacco to cigarettes was out of concern for health . At the turn of the century, tuberculosis was still an uncontrolled disease, representing a major cause of early death nd disability. Some of the prevailing medical opinion of the day was that "spitting" spread the TB germ--thus public expectoration increasingly become socially unacceptable; and many localities passed ordinances prohibiting public spitting. this helped encourage the uptake of cigarettes by men who represented the major demographic group of tobacco users.

When individual cohorts of men and women are examined, it is quite evident that each adopted smoking as a life-style at different rates. Peak life-time prevalence for males occurred among those cohorts born from 1900 through the 1930's (Figure 2) whereas among women peak prevalence did not occur until the appearance of cohorts born 1930 and thereafter (Figure 3). Some older age cohorts of men had smoking prevalence which exceeded 80 percent--that is 80 percent or more had been regular smokers at some time during their life. No cohort of women ever achieved this high prevalence rate. The highest smoking rate observed for any cohort of women was around 50 percent ever smokers.

Differences in uptake and use of cigarettes between men and women account for many of the differences observed for some smoking related cancers and other diseases related to cigarette and tobacco use. Substantial differences also exist with respect to their quitting behavior.

In 1964, when the first Surgeon Generals Report on Smoking and Health was published, over half of all males (53 percent) were regular cigarette smokers; compared to only on-third of women (34 percent). [In 1955 over 50 percent of males were regular smokers, but smoking by women was only half that of males, with 25 percent regular smokers.] In 1985, 33 percent of males were smokers, compared to 28 percent of women (Figure 4). Thus, substantial numbers of men compared to women have quit smoking. These differences in cigarette use rates between current and past cohorts of men and women will have a profound effect on mortality and morbidity patterns in the United States for years to come. Lung cancer deaths have already reported to have surpassed those for breast cancer in women. While the lung cancer death rate continues to rise for both men and women, among women, an increasing rate of increase is observed compared to a decreasing rate of increase in men. This changing pattern of lung cancer mortality reflects the declining percentage of smokers among men as well as their relatively higher quit rates, and lower rates of smoking initiation among contemporary age cohorts of men compared to women.

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The Health Consequences of Active Cigarette Smoking

Cigarette smoking is now recognized as the Nations single largest cause of premature death and disability. Estimates of the number of premature deaths annually caused by cigarette smoking range from between 270,000 to 475,000. It can reasonably be concluded that between 300,000 and 350,000 preventable deaths can be attributed to smoking in this country. The number of persons suffering from chronic disabling diseases and conditions runs in the tens of millions.

Every medical authority and organization who has objectively examined the evidence linking smoking to early death disability has reached a similar conclusion. The data base upon which a judgement can be made concerning smoking as a substantial health threat is staggering--over 50,000 citations from dozens of cultures are not in the published scientific literature. Cigarette smoking has probably been the most studied agent in the environment, but it has only been within the pst 25 years that medical and scientific opinion have become galvanized into doing something about its control. The need for control measures has become more evident with the accumulation or medical evidence linking not only ill effects to the smoker, but also possible chronic health effects on nonsmokers who live or work around smokers has emerged.

Smoking and Cancer

In the 1982 Surgeon Generals Report, the U.S. Public health Service identified a causal role between cigarette smoking and a variety of cancer sites. Cancers causally related to smoking include lung cancer, and cancers of the larynx, esophagus and oral cavity; smoking was also judged a contributing factor for the development of cancers of the bladder, kidney, and pancreas. More recently evidence has accumulated which suggest a causative role between cigarette smoking and cancer of the uterine cervix in women. Most estimates published in the scientific literature indicate that nearly on-third of all cancer deaths that occur annually in the U.S. result from cigarette smoking. Thus, approximately 140,000 cancer deaths occurred last year because of smoking--the majority of these cancers are of the respiratory system. Lung cancer alone is responsible for fully one-quarter of all cancer mortality; were it not for lung cancer we would be experiencing a substantial decline in the cancer death rate in the United States. Approximately 85 to 90 percent of all lung cancer deaths are smoking related.

The evidence linking smoking and excess cancer mortality is so strong that only the tobacco lobby continues to claim that no causative role has been established. An examination of the association between cigarette smoking and lung cancer graphically

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illustrates smoking's role in the causation of neoplastic diseases.

A number of epidemiological studies published during the last two decades provides an abundance of data to analyze. In particular are the major prospective studies on smoking and health. These studies, conducted in the Untied States, Canada, England, Japan and Sweden represent some of the largest population based studies ever undertaken by medical science (Table 1). They involved enrolling healthy men and women into a study design and then following these individuals over time. Numerous factor about them were recorded including where they lived, their occupations, dietary habits, whether they used tobacco, access to health care, and many other factors. As a group, these eight studies in the United States, the U.S. Veterans Study and the American Cancer Society (ACS) 25-State Study contained cohorts of 290,000 and 1 million persons respectively. The Veterans Study continues to this day and this cohort has been followed prospectively for 26 years. These studies can provide significant insight into the association between smoking and lung cancer.

Lung Cancer

Lung cancer mortality rates are strongly influenced by the total dose or cigarette smoke received. If one smokes more cigarettes per day, inhales deeply, if they started smoking at an early age had has smoked for many years, the risk for lung cancer is increased dramatically.

The most often used measure to gauge lung cancer mortality is the number of cigarettes consumed daily. In the ACS 25 State study, for example, among males smoking less than 1/2 pack per day their lung cancer rate was nearly 5 times greater than that of a nonsmoker. With each increase in the number of cigarettes consumed daily, a corresponding increase in lung cancer mortality is observed (Figure 5). For those smokers consuming two or more packs daily, their lung cancer mortality is between 15 and 25 times greater than that of the nonsmoker. Translated, this means between a 1,500 and 2,500 percent greater likelihood of developing and dying of lung cancer in heavy smokers compared to individuals who have never smoked.

An inverse dose-response relationship exists between an early age of regular smoking initiation and lung cancer mortality. In the U.S. Veterans Study, those smokers who started smoking in their early teens had substantially higher lung cancer death rates that those who started in their late teens or twenties (Figure 6). Those who began smoking before age 15 experienced an 18-fold greater lung cancer mortality, compared to a slightly greater than 5-fold excess risk for those who initiated their behavior after age 25.

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Generally, the number of years one has smoked and the inhalation patterns (Figure 7) ar also strongly correlated with increased lung cancer death rates in smokers compared to nonsmokers.

In summary, the greater the life-term exposure to tobacco smoke, the greater the risk. When the agent is removed, for example if an individual quits smoking, their lung cancer risk begins to decline (Figure 8). This risk continues to decline relative to the continuing smoker an after about 15 years off cigarettes the former smoker's lung cancer risk begins to approximate that of the lift-long nonsmoker. However, it appears that some excess risk may be carried throughout life, although this risk is strongly influenced by the individual;s total life-time exposure to the agent and the total number of years of smoking cessation.

Coronary Heart Disease

Coronary heart disease (CHD) continued to be this nation's leading cause of death, and for nearly 20 years, medical research has shown that smoking is one of the major independent risk factors or causes of CHD (along with high blood pressure and high cholesterol levels). In the final report of the Pooling Project, an interaction between smoking and other risk factors was observed (Figure 9). Each independent risk factor contributed about the same increased level of risk, however, when two or more factors wee present, the risk of a major CHD event was increased beyond the sum of the independent risk--thus, a synergistic effect was created when two or more risk factors were present.

The independent risk of CHD for smoking is greater at the younger age groups although the greatest number of excess CHD deaths due to smoking actually occurs in the older age groups (Figure 10). Smoking has also been shown to increase the risk for other cardiovascular diseases, including peripheral vascular disease, cerebrovascular disease (at younger age groups), and aortic aneurysms. For women, smoking can interact with oral contraceptives to greatly increase the risk for fatal and nonfatal myocardial infarction and subarachnoid hemorrhage.

Many public health estimates place the total number of excess cardiovascular disease deaths due to smoking to be greater than those due to cancer. Up to 30 percent of all CHD deaths may be due to cigarette smoking and its interaction with other risk factors.

Chronic Obstructive Lung Disease

While the number of deaths classified as chronic obstructive lung disease (COLD) are much smaller than those for cancer or

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cardiovascular disease, COLD represents a group of diseases which affect millions of individuals. These diseases, which include emphysema, can be severely debilitating and represent a substantial number of people who become disabled due to their condition, unable to work or even seek employment.

For many years cigarette smoking has been known to increase the risk of developing and dying from COLD. Even the first Surgeon Generals Report issued in 1964 identified a causative role between smoking and chronic bronchitis. As with lung cancer, the risk of contracting and dying from COLD is substantially elevated among smokers (Figure 11) and this risk increases with an increasing dose of cigarette smoke received. Mortality rations for COLD in smokers versus nonsmokers are very high, exceeding 30 to 1 for heavy smokers (Figure 12).

Smoking also has a dramatic effect on lung function. The normal rate of lung function decline observed with increasing age is accelerated in cigarette smokers (Figure 13). While quitting smoking can reverse this decline so that the continuing decline resembles that of the nonsmoker, there is little evidence to suggest that former smokers regain any of the previously lost lung function.

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TABLES AND FIGURES, CHAPTER 2

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CHAPTER 3

THE ODOR AND IRRITATION OF ENVIRONMENTAL TOBACCO SMOKE

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Introduction

The atmosphere inside buildings contains many chemicals generated by the presence and activities of people. People's bodies give off small quantities of organic materials in the breath and from the skin and alimentary tract. Although a chemical analysis may reveal hundreds or even thousands of materials, we usually perceive them in the aggregate as what we call body odor or sometimes occupancy odor. We often notice it consciously when we enter a hot, muggy room. Nevertheless, body odor exists in occupied spaces at essentially all other times, but remains at a low level because of ventilation with outside air. When engineers and public health specialists began to study ventilation requirements for buildings quantitatively, they started with the smell of occupancy (Cain, 1979). The fresh-air requirements so derived exceeded those based on metabolically-relevant gases (oxygen, carbon dioxide) several-fold.

In general, occupancy odor poses a mild challenge to the HVAC engineer. (HVAC refers to heating, ventilating, and air-conditioning.) This odor constitutes the baseline case. Anything else that people do in the space will increase ventilation requirements. This would include cooking, painting, operating machines (e.g., mimeo, photocopier), woodworking, smoking, and so on. Of these various activities, smoking has traditionally been pervasive and has accordingly received specific attention (Yaglou, 1955; Kerka and Humphreys, 1956; Weber, Jermini, and Grandjean, 1976).

As with occupancy odor, the HVAC engineer has confronted environmental tobacco smoke (ETS) via its sensory characteristics, i.e., its odor and irritation, rather than via its chemical or physical complexity. The chemical complexity of ETS likely exceeds that of emissions from bodies and a chemical analysis of ETS-containing air offers little of practical significance regarding the origin of its, odor or irritation.

In what follows, we shall review how human beings perceive ETS. We shall ask: How much ventilation air must we introduce

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into a space in order to satisfy visitors to that space? Will the amount of air required by smokers differ from that required by nonsmokers? Does ETS-odor decay spontaneously after smoking ceases? Do occupants accustomed to the environment impose less stringent criteria for ventilation than visitors fresh from a nonsmoking space? Does the odor and irritation of ETS come from the smoke particles or from the vapors that accompany the particles? Does filtration offer opportunities for control?

Ventilation Requirements Based on Responses of the Visitor

The usual setting to explore how indoor contaminants affect the senses is a climate-controlled environmental chamber with relatively inert surfaces, e.g., aluminum or stainless steel, and variable ventilation. In the case of occupancy odor, human beings occupy the chamber in order to generate the odor of interest. Judges may enter the chamber briefly or may place their faces into a box fed with the atmosphere of the chamber. (In their manner of sampling the atmosphere, the judges essentially the space.) The odor judgment may comprise a mark on an annotated rating scale (e.g., 'no odor' to 'overpowering odor') or the choice of a matching odor intensity. The latter judgment generally entails the use of a device called an olfactometer that delivers the vapor of some standard odorant, such as n-butyl alcohol (1 -butanol), at various concentrations. A matching odor has the advantage of reproducibility from lab to lab.

Many modern investigations also obtain judgments of acceptability in order to 'calibrate' intensity judgments. Acceptability judgments address the question: How many people will object to any given level of odor (or irritation)? The answer will depend on individual differences in olfactory sensitivity and on esthetic criteria. Whereas we can expect average intensity judgments to remain constant through the decades for any fixed stimulus, we can expect acceptability judgments to shift somewhat with prevailing standards.

A comment by N. W. Downes following the presentation of a classic study of ventilation requirements for occupancy odor by Riley, Yaglou, and Coggins (1936) illustrates the matter of shifting standards:

> This paper brings to mind an experience we had in Kansas City some years ago. We built a 30-room elementary school... equipped with a ... fan system...so dampered that not only outside air in toto could be used but air cou*ld be recirculated on a basis of one-third, two-thirds or in toto, the air supplied remaining constant at 30 cfm per pupil. We soon found we were getting no place on a recirculation basis on account of odors which were at times nauseating. Even the use of outside air in toto failed to eliminate the objections. The Principal on investigation soon found that a

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large number of these youngsters were sent to school by their parents literally sewed up for the winter. He immediately took it upon himself to change the situation by requiring each chi*ld to take a warm shower bath once a week at the school, although encountering vigorous opposition from some of the parents. The objectionable odors soon disappeared as did the objections from the parents. [p. 158]

Figure 1 depicts how occupancy odor varied with ventilation rate per occupant under nonsmoking occupancy in a recent study conducted in a climate chamber (Cain, Leaderer, Isseroff, Berglund, Huey, Lipsitt, and Perlman, 1983). Visitors made judgments of air circulated through an outside sampling-box and were therefore naive to the conditions of occupancy. The scale refers to the concentration of 1 -butanol matched to the occupancy odor present after one hour of occupancy. Just as odor level decreased with increases in ventilation rate, so also did dissatisfaction. The point of 20% dissatisfaction holds special interest.

The ventilation standard of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) (1986) recommends a maximum of 20% dissatisfaction among visitors to a space. By this criterion, the data from the investigation imply the need for 17.5 cfm per occupant. The ASHRAE standard suggests 15 cfm or more per occupant for most spaces, e.g., 15 cfm for classrooms, libraries, auditoriums, dormitories; 20 cfm for offices, conference rooms, dining rooms, lobbies; 25 cfm for discos, beauty shops; 30 cfm for bars, casinos; 60 cfm for smoking lounges (see Fig. 2). Hence, practice coincides with the experimental data about as well as could be expected regarding the baseline case.

When cigarettes were smoked in the climate chamber, odor level increased markedly. Figure 3 displays ETS odor for various conditions of smoking: intermittent (4 cig per hr) or continuous (8 or 16 cig per hr). As Fig. 4 shows, the degree of dissatisfaction mirrored the higher odor level. Based on the rule of 20% maximum dissatisfaction, the ventilation rate required per cigarette during active smoking exceeded 4,000 ft3. In order to convert ventilation per cigarette into ventilation rate per person for typical conditions of occupancy in a 'smoking-permitted' space, we assumed that 10% of occupants would be smoking at any given time. The resulting rate equalled 53 cfm, more than three times that for nonsmoking occupancy.

Does the higher ventilation rate for smoking imply that the judges in the investigation showed a special aversion to the odor of cigarettes? Apparently not. The judges, one-third of whom were smokers and two-thirds of whom were not, seemed to base their dissatisfaction strictly on odor intensity. Degree of dissatisfaction varied with odor intensity in the same way for

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both occupancy odor and tobacco smoke odor (Fig. 5). Stronger odors meant greater dissatisfaction irrespective of odor type.

How well does the higher rate implied by the investigation compare with the ASHRAE standard? As indicated above, the standard recommends 60 cfm per occupant in a smoking lounge, where presumably most or all occupants will be smoking. If 100% rather than 10% were smoking simultaneously, then the rate would need exceed an unachievable 500 cfm per occupant. If 50% were smoking, perhaps a more realistic expectation, then the rate would need to exceed a still unachievable 250 cfm per occupant. (The maximum achievable rate for typical design occupancy in a mechanically-ventilated space will usually equal about 60 cfm per occupant, though a generous allotment of space per person can increase that value.) Fortunately, however, the smoker seems less concerned about the odor of ETS than the nonsmoker. As it turns out, smokers as a group seem satifisfied with about one quarter the ventilation air of a mixed group containing a typical proportion of smokers and nonsmokers. Hence, a rate of 60 cfm per occupant may actually almost meet the customary ASHRAE criterion of a maximum of 20% dissatisfaction.

How about nonsmokers? Just as a group of smokers will hold a less stringent criterion than the mixed group, a group of nonsmokers will hold a more stringent criterion. The data from the investigation suggest that under typical conditions of smoking occupancy (10% smoking at any given time) nonsmokers would need over 100 cfm per occupant to hold dissatisfaction at only 20% . At the present time, we do not know whether the difference between smokers and nonsmokers derives from olfactory sensitivity to ETS or to esthetic criteria. Nevertheless, it would appear that where smoking occurs none of the recommendations of the ASHRAE standard will do for the nonsmoker.

Clausen (1986) confirmed differences in tolerance of ETS odor between smokers and nonsmokers. For any given level cf odor (expressed as concentration of butanol), a group of nonsmokers expressed much more dissatisfaction than smokers (Fig. 6). Both groups exhibited a lawful relation between odor intensity and dissatisfaction, but the difference between the groups grew as odor level increased. At the point where 20% of smokers expressed 'dissatisfaction, the majority of nonsmokers did so.

As ETS enters the atmosphere, its many chemical constituents react with each other and with surrounding materials both chemically and physically. Does this behavior change the nature of the contaminant over time? Yes and no. Irrespective of whatever chemical changes occur, the odor of ETS behaves in the short run like a stable contaminant. After the source has been removed, ETS odor decays in a manner entirely predictable from ventilation rate (Clausen, Fanger, Cain, and Leaderer, 1985). In this respect, it differs from occupancy odor which has a

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half-life of 55 min, presumably dictated by slow oxidation of its chemical constituents into less odorous products (Clausen, Fanger, Cain, and Leaderer, 1986). ETS odor offers no such easy benefit to the engineer. Indeed, when ventilation fails to eliminate the contaminant entirely, ETS carries a penalty derived from its physical interaction with surfaces. Because the liquid aerosol of ETS, known in the aggregate as 'tar,' adsorbs strongly to walls, fabrics, and so on, it becomes a source of odor later. The background odor of the emitted products carries its own demands for ventilation, predictable in part from the typical amount of smoking in a space (Clausen, Moller, Fanger, Leaderer, and Dietz, 1986).

In a laboratory situation where other sources of combustion can be eliminated, carbon monoxide can offer a gross index of level of ETS. Figure 6 shows that Clausen could relate dissatisfaction to concentration of carbon monoxide in ETS as well as to matched level of butanol. This occurred because of a strong correlation ($r>0.90$) between odor intensity and incremental carbon monoxide due to smoking. Such a relationship makes it possib*le to compare one study to another. We can ask, At what concentration of carbon monoxide will ETS reach a given level of dissatisfaction in one or another group? As Fig. 6 revealed, the concentration at which 20% of nonsmokers will express dissatisfaction falls about eight times below that at which 20% of smokers will express dissatisfaction.

Responses of Occupants

Up to this point, we have concerned ourselves only with the reactions of visitors. Standards for ventilation have focused on the reactions of the visitor, rather than those of the occupant, because the visitor will have a more sensitive, and hence more critical, nose than the person adapted to the contaminant. On the other hand, a focus on the visitor sidesteps another important time-dependent sensory response of the occupant, irritation. Whereas air containing an irritant may seem only barely irritating at first, it may become intolerably so over time.

Figure 7 illustrates the time-course of eye irritation experienced by occupants exposed to ETS at constant concentrations of 2 or 5 ppm carbon monoxide, used here as a tracer in the manner mentioned above (Cain, Tosun, See, and Leaderer, 1987). The lower concentration led to slight, though statistically significant, irritation above pre-smoking baseline. The higher concentration led to irritation that increased over time in sensory magnitude and caused an increasing degree of dissatisfaction. Whereas essentially none of the occupants found the irritation objectionable at first, by the end of an hour about 30% found it so. In an extension, Clausen, Nielsen, Sahin, and Fanger (1987) found that an asymptotic level of 20%

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dissatisfaction would occur at a concentration of 3.8 ppm carbon monoxide. A comparison with the odor judgments of visitors in Fig. 6 reveals that only smokers would find such a level tolerable at the 20% rule. Clausen et al. estimated that the ventilation rate necessary to control irritation of occupants to a dissatisfaction of 20% would equal only one-tenth of that needed to control odor perceived by visitors to the same level of dissatisfaction.

Although Clausen et al. did not argue in favor of lowering ventilation to meet only the dissatisfaction of occupants, there could exist some temptation to do so (see Winneke, Plischke, Roscovanu, and Schlipkoeter, 1984). Cain et al. cautioned against the temptation to see irritation and odor in the same light:

> Apart from the issue of whether visitors or occupants are more sensitive, there exists a question regarding whether the '20% rule' should govern dissatisfaction based on irritation just as it governs dissatisfaction based on odor alone.
>
> Whereas odor may be interpretable narrowly on grounds of comfort, irritation would seem interpretable on grounds of health. Some people may find themselves quite neutral with respect to one or another odor, but no one could plausibly argue neutrality with respect to burning eyes. It could be argued, therefore, that any consistent irritation above baseline should be deemed unacceptable. [p.352]

Alternatives to Ventilation

It might seem intuitively reasonable that the odor of ETS should come from its vapor phase and the irritation from its particulate phase. At one time this seemed likely, but recent investigations that have employed electrostatic air cleaning have shown clearly that the gas phase accounts for most of both odor and irritation (cf. Hugod, *1984; Weber, 1984). Comparison of the right and left sides of Fig. 7 will reveal that elimination of the particulate phase had only a trivial effect on the eye irritation caused ETS at 2 and 5 ppm carbon monoxide (Cain, Tosun, See, and Leaderer, 1987). The same held true for judgments of odor and of nose and throat irritation. Clausen, Nielsen, Sahin, and Fanger (1987) confirmed these results. In finding that particles played essentially no role in odor, both investigations also confirmed Clausen et al.'s (1985) earlier experiments with visitors. Hence, particle filtration holds no promise for immediate elimination of the discomfort of ETS. The major advantage of such air cleaning will derive from reduction of haze and collection of 'tar' that would otherwise adsorb elsewhere in the space.

Although both the odor and irritation of ETS come from the

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vapor phase, the chemical constituents that give rise to the one, probably do not give rise to the other. Undoubtedly, the odor comes from a very large number of constituents. The sense of smell will respond to almost all airborne organic materials present in sufficient concentration (Cain, 1988). For one substance, however, a 'sufficient concentration' may fall a millionfold below that of another. Furthermore, individual constituents will combine perceptually in mixtures in complicated, nonlinear ways. Although one or a few materials could in principle dominate the odor, it seems unlikely.

Many fewer materials can cause irritation at the concentrations present in ETS and its irritation could realistically arise from a few or perhaps even one constituent. Little is known about how irritants combine with each other perceptually though it is known that odor and irritation interact (Cain and Murphy, 1980). Irritation can surpress the perception of odor and vice versa (Cain, See, and Tosun, 1986). In so far as irritation may have less complex origin than odor, it may offer easier opportunities for control through filtration. As yet, however, experiments on the origin of ETS have told more about what fails to cause irritation than about what causes it (Weber, Jermini, and Grandjean, 1976; Weber-Tschopp, Fischer, and Grandjean, 1977; Weber-Tschopp, Fischer, Gierer, and Grandjean, 1977; Hugod, Hawkins, and Astrup, 1978).

The complexity of ETS more or less guarantees that almost any means of air cleaning will eliminate part of it, even though no simple procedure will eliminate all of it. Through the use of air washing that presumably eliminated some water-soluble constituents, Clausen, Moller, and Fanger (1979) achieved some reduction in level of dissatisfaction though not in the perceived intensity of ETS. The air-washed ETS smelled fresher. The results offered little encouragement for the use air-washing alone, but, showed that the odor character of ETS can play some role in degree of acceptance.

Undoubtedly, a combination of particulate air cleaning and vapor-phase cleaning via adsorption on activated carbon or via chemisorption on oxidant-impregnated alumina can control both the irritation and odor of ETS to some degree. Unfortunately, there exist no standards to assess the efficacy of vapor-phase filtration media. The installation of such media occurs more commonly in special environments, e.g., libraries and computer facilities, under expert guidance than in spaces designed for genera*l occupancy. In the overwhelming majority of cases, attempts to control ETS rely on ventilation (dilution). As we have seen, however, ventilation has its limitations.

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Figure Captions

Figure 1. Showing the relation between level of occupancy odor (indicated by concentration of 1-butanol matched to the odor) and ventilation rate per occupant when 4 to 12 persons occupied a climate chamber for an hour. Judgments of odor were made by visitors who sampled the air of the chamber at a remote sampling box. Also shown is the frequency of dissatisfaction expressed by the visitors in response to the question, Is the air acceptable or unacceptable? Data from Cain et al. (1983).

Figure 2. Frequency distribution of ventilation rates *. recommended for various types of spaces (e.g., offices, auditoriums, ticket booths, waiting rooms) by the ASHRAE standard on ventilation and indoor air quality.

Figure 3. Showing the intensity of ETS odor perceived by visitors to the sampling box during and after intermittent (4 !cig/hr) or continuous (8 and 16 cig/hr) smoking in the climate chamber. Results are expressed relative to level of butanol matched to odor during presmoking occupancy. The open squares in. the left panel show a function for nonsmoking occupancy for comparison. Ventilation rate per occupant under smoking conditions refers to smokers, who were the only occupants in the chamber. From Cain et al. (1983).

Figure 4. Percent dissatisfaction among visitors vs ventilation during the last 15 min of smoking in the experiment shown in Fig. 3. Ventilation rate per cigarette based on 7.5-min smoking time per cigarette. Ventilation rate per occupant adjusted to typical conditions of smoking occupancy where 10% of occupants will be smoking at any give time. Modified from Cain et al. (1983).

Figure 5. Percent dissatisfaction vs odor intensity (graphic rating) during smoking and nonsmoking occupancy. Data from Cain et al. (1983).

Figure 6. Left: Percent dissatisfaction vs odor intensity (matched level of butanol) judged by smokers and nonsmokers. Right: Percent dissatisfaction vs increment in concentration of airborne carbon monoxide. Modified from Clausen (1986).

Figure 7. Perceived magnitude of eye irritation and degree of dissatisfaction expressed by occupants exposed to ETS for an hour. Concentrations of carbon monoxide were held constant throughout the exposures and indicate severity of exposure. Filtration refers to elimination of particles via electrostatic precipitation. Filtration had little effect on irritation. From Cain et al. (1987).

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TABLES AND FIGURES, CHAPTER 3

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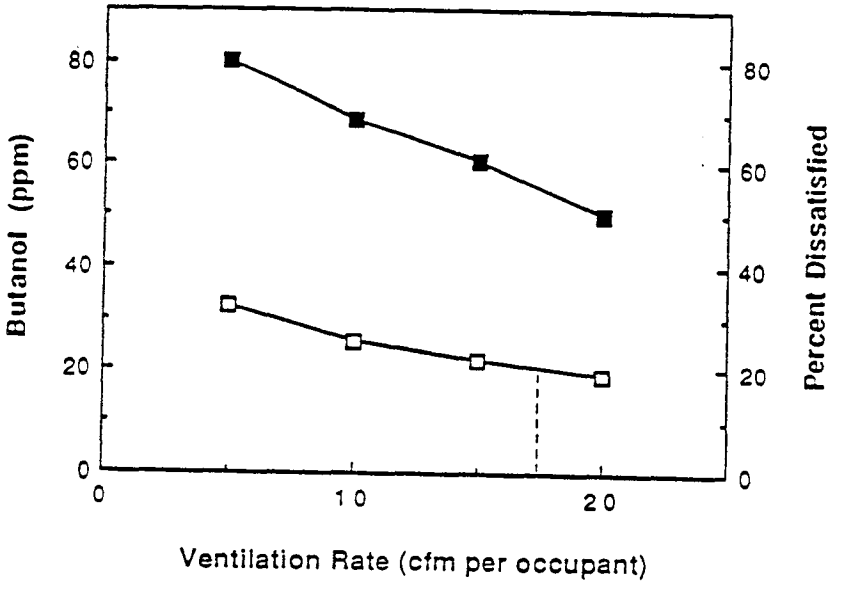

Figure 1

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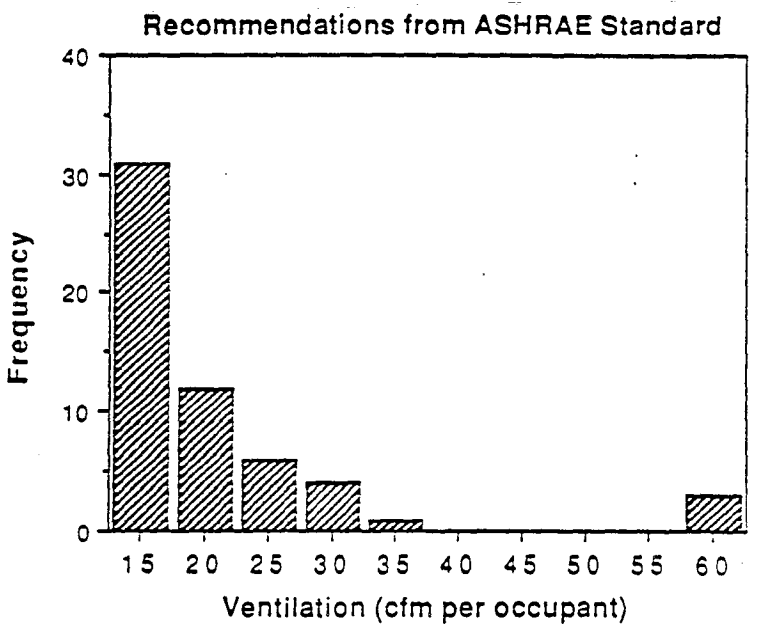

Figure 2

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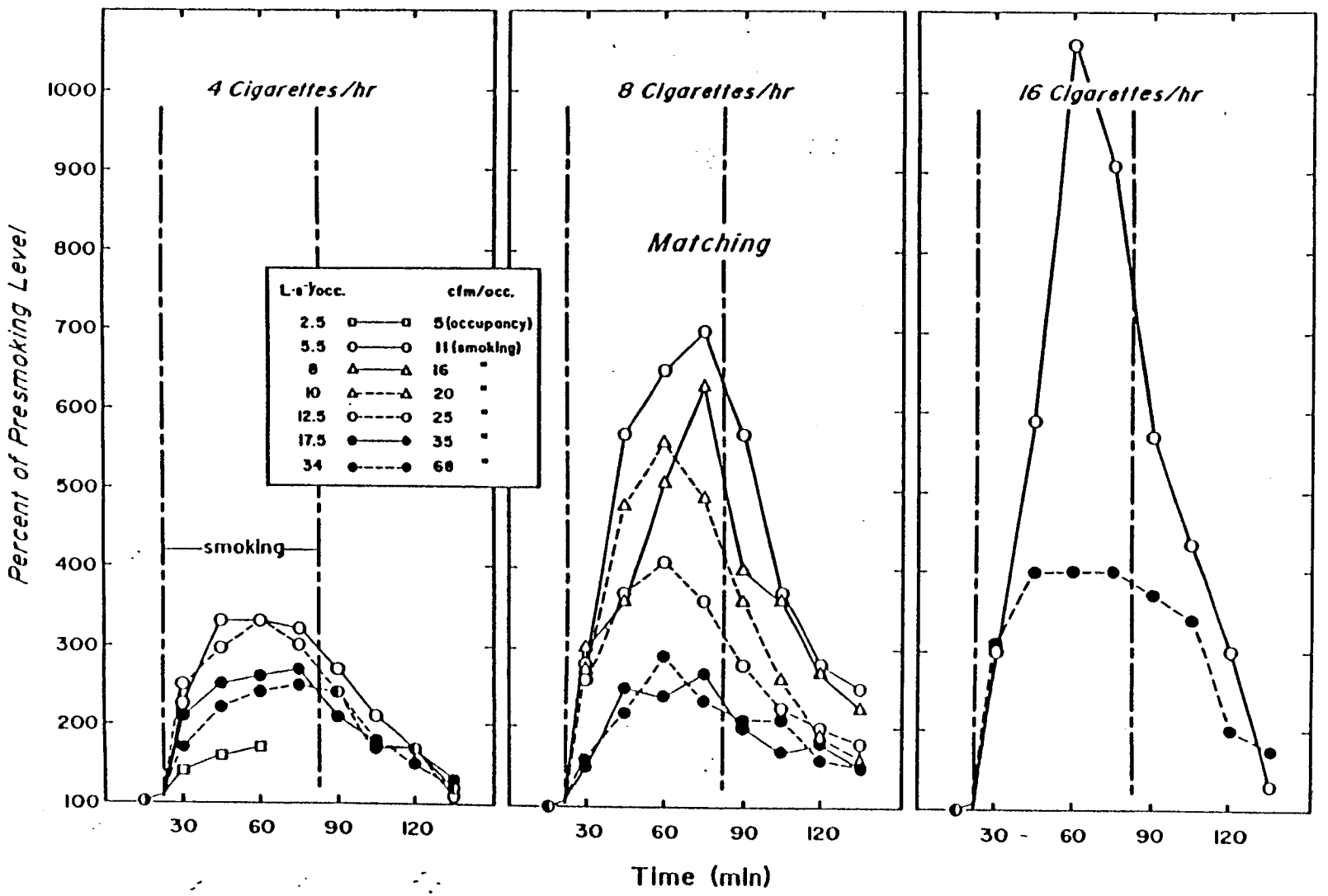
Figure 3



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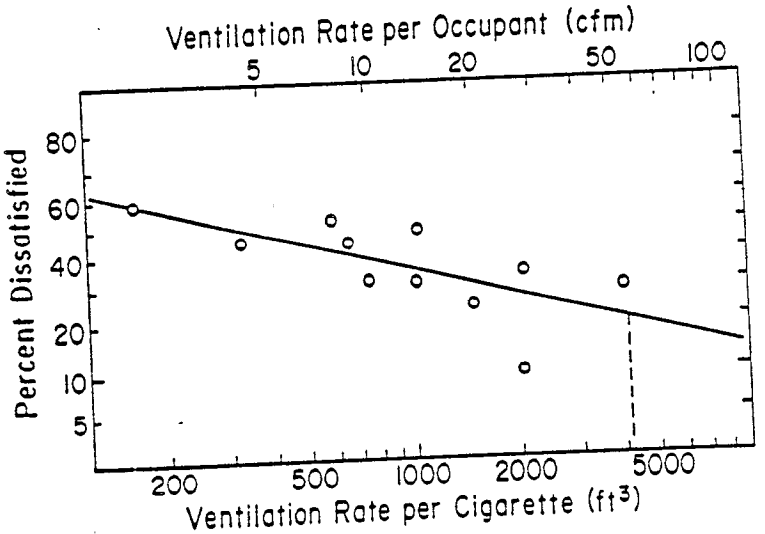

Figure 4

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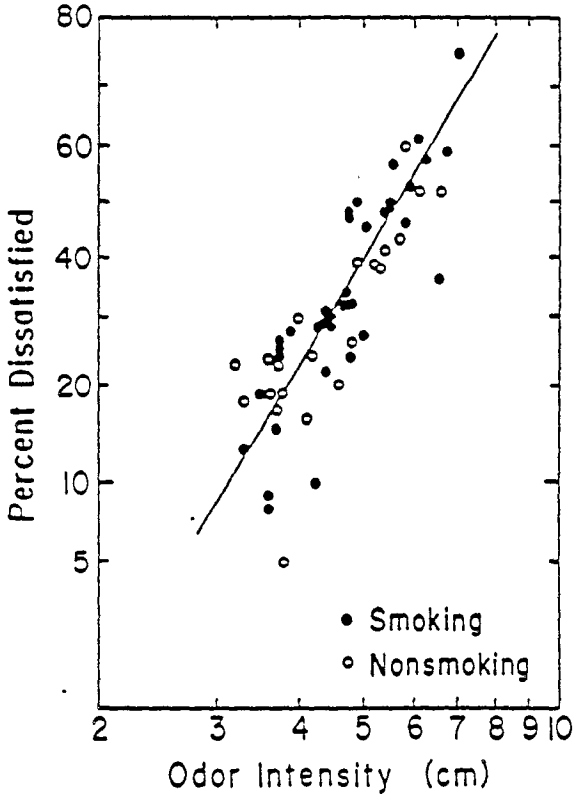

Figure 5

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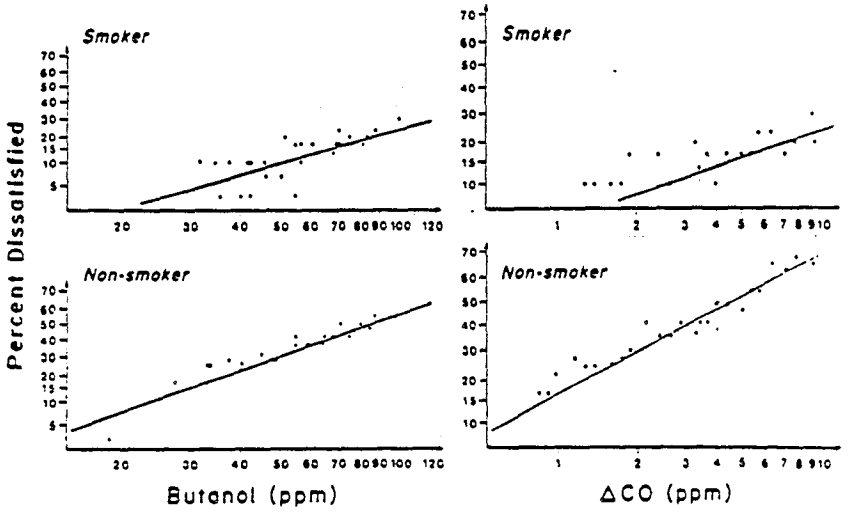

Fig 6

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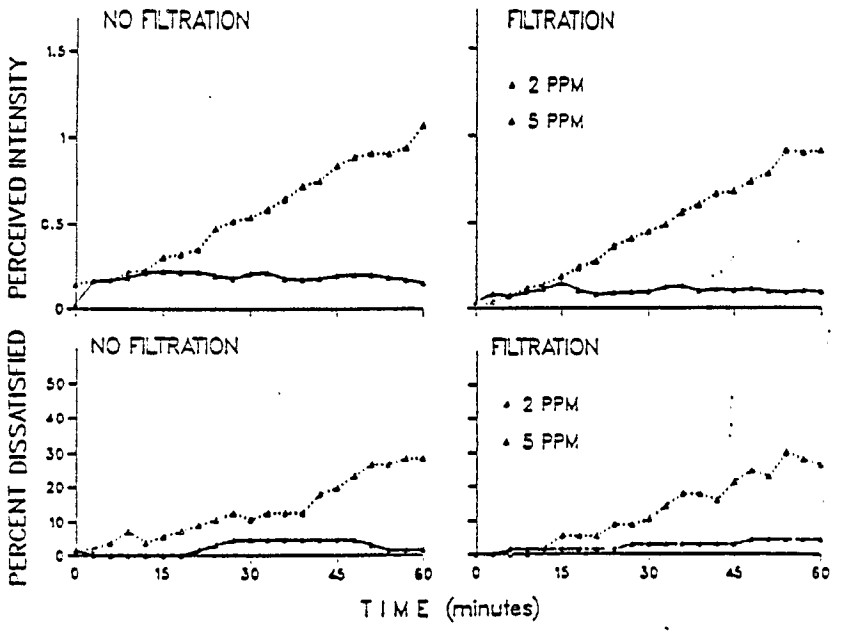

Fig. 7

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Environmental Tobacco Smoke and Cancer

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Introduction

Lung cancer, an uncommon malignancy at the start of the century, has become the leading cause of cancer death in the United States (U.S. DHHS 1982). Approximately 150,000 lung cancer deaths will occur in the United States in 1989. Most cases are rapidly fatal and only a small proportion are cured by surgery or chemotherapy; five-year survival following diagnosis is less than 10 percent. Most lung cancers arise in the larger airways of the lung, the predominant site of deposition of inhaled particles in the size range of 0.5 to 3.0 microns in aerodynamic diameter. Primary cancer of the lung occurs in multiple histopathological patterns that are generally distinct and classifiable by conventional light microscopy. The principal types are squamous cell carcinoma, small cell carcinoma, adenocarcinoma, and large cell carcinoma; in the general population, these four types account for approximately 30 percent, 20 percent, 25 percent, and 15 percent, respectively, of all lung cancers (Butler et al. 1987). Bronchioloalveolar cell carcinoma represents about 5 percent of the remaining lung cancers. The cellular origins of the various cell types have not been established, and controversy remains concerning the specificity of associations between certain cell types and specific etiologic agents.

The epidemic rise of lung cancer during this century stimulated laboratory and epidemiological investigation of its causes. Most of the early evidence indicated that tobacco smoke was a potent respiratory carcinogen, and in 1964 the Advisory Committee to the Surgeon General of the U.S. Public Health Service concluded that cigarette smoking is a cause of lung cancer (U.S. PHS 1964). Subsequent investigations have been uniformly consistent with this conclusion. The association of lung cancer with cigarette smoking is strongest for squamous cell and small cell cancers, but the other major types are also caused by cigarette smoking. In active cigarette smokers, the risk of lung cancer increases with both the amount smoked on a daily basis and with the duration of smoking (U.S. DHHS 1982; Doll and Peto 1978; Pathak et al. 1986). A threshold level of smoking that must be exceeded to cause lung cancer has never been demonstrated; any cigarette smoking is considered to increase lung cancer risk beyond that of the lifelong nonsmoker. In former smokers, the risk of lung cancer declines exponentially in comparison with those who continue to smoke.

Agents other than tobacco smoke may also cause lung cancer, and cases occur in lifelong nonsmokers. A recent study in New Mexico showed that the lifetime risks of lung cancer were 0.5 percent and 1.1 percent in female and male nonsmokers, respectively (Samet et al. 1988). Occupational exposures to arsenic, asbestos, chloromethyl ethers, chromium, coke oven fumes, nickel, and radon daughters have been linked to increased lung cancer risk, and many other occupational agents are suspect respiratory

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carcinogens. A family history of lung cancer is also associated with increased lung cancer risk, although a clear pattern of genetic susceptibility to lung cancer has not been demonstrated. Outdoor air pollution may contain carcinogens and indoor air may have high levels of radon, which causes cancer in exposed underground miners. Animal and human studies suggest that low consumption of vitamin A or its precursor, beta-carotene, may also increase lung cancer risk.

While studies linking active smoking to lung cancer were first published in the late 1940s and early 1950s (U.S. PHS 1964), involuntary exposure of nonsmokers to tobacco smoke was not considered as a cause of lung cancer in nonsmokers until 1981 when the first two scientific papers on this subject were published. Subsequently, many additional reports have addressed involuntary smoking as a cause of lung cancer in nonsmokers, and the World Health Organization (1986), the U.S. Surgeon General (U.S. DHHS 1986), and the National Research Council (1986) have reviewed the evidence and judged it sufficient to support the conclusion that involuntary inhalation of tobacco smoke by nonsmokers causes cancer. This chapter reviews the evidence on involuntary smoking and lung cancer from human populations, and the conclusions of these organizations. The chapter also addressess the more limited evidence on involuntary smoking and cancer at sites other than the lung.

The Epidemiological Approach

Epidemiology is the scientific method used to describe the occurrence of disease in human populations and to determine the causes of disease by studying populations. Descriptive measures of disease occurrence include the incidence rate, which is the rate at which new cases of disease develop; the mortality rate, or rate of death; and the prevalence rate, which is the proportion of the population with disease. To identify the causes of disease, epidemiologists generally perform either cohort or case-control studies. Each type of study provides an estimate of relative risk as a measure of the association between exposure and disease. The relative risk describes the comparative occurrence of disease in exposed compared with nonexposed persons.

In a cohort study, the subjects are selected on the basis of their exposure history and followed over time for the development of disease. For example, a study of involuntary smoking and lung cancer might be performed by enrolling nonsmokers married to smokers and another group of nonsmokers married to nonsmokers. The lung cancer risk associated with marriage to a smoker would be estimated by comparing incidence or mortality from lung cancer in the two groups.

In a case-control study, cases with the disease of interest and controls without the disease are identified and their past

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exposures to factors of interest are assessed, often by interview. For example, a case-control study of lung cancer and involuntary smoking might be conducted by identifying nonsmokers with lung cancer and a suitable control group, and then interviewing the subjects concerning the smoking habits of their spouses, other household members, and colleagues at work.

Each type of study has advantages and disadvantages, and the results of both types may be distorted by bias. Misclassification of exposure is of particular concern in studying lung cancer and involuntary smoking. Misclassification of exposure refers to the incorrect categorization of actually exposed subjects as nonexposed and of nonexposed as exposed. When misclassification occurs randomly, it tends to bias studies towards showing negative results; if nonrandom, it may exaggerate or reduce the apparent effect of an exposure. With regard to involuntary smoking and lung cancer, two types of misclassification are of concern. Subjects classified as nonsmokers may have actually been active smokers and the degree of exposure of nonsmokers to the smoking of others may not be accurately classified. Misclassification of both types is discussed below in relationship to specific studies.

The diagnosis of lung cancer is also subject to misclassification; a cancer that originated at another primary site and then spread to the lung may be incorrectly diagnosed as a primary cancer of the lung. For example, in the case-control study reported by Garfinkel and colleagues (Garfinkel et al. 1985), 13 percent of cases originally diagnosed as lung cancer were reclassified to other sites after histological review. With regard to exposure misclassification in this study, 40 percent of the cases initially classified as nonsmokers on the basis of information in medical charts were found to be smokers on interview.

Epidemiological Evidence on Involuntary Smoking and Lung Cancer

Evidence concerning involuntary smoking and lung cancer has been sought indirectly in descriptive data on mortality rates and directly with case-control and cohort studies. Time trends of lung cancer mortality across this century in nonsmokers have been examined with the rationale that temporally increasing exposure to environmental tobacco smoke should be paralleled by increasing mortality rates (Enstrom 1979; Garfinkel 1981). These data can only provide indirect evidence on the lung cancer risk associated with involuntary exposure to tobacco smoke. Enstrom (1979) calculated lung cancer mortality rates from various nationwide sources for the period 1914-1968 and concluded that a real increase had occurred among males after 1935. In contrast, Garfinkel (1981) did not identify time trends of lung cancer mortality in nonsmoking participants in two cohort studies, the Dorn Study of U.S. veterans, 1954 to 1969, and the American Cancer Society study, 1960-1972.

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Most of the case-control and the cohort studies indicate increased lung cancer risk in nonsmokers married to smokers, but these studies do not uniformly show increased risk for sources of exposure other than smoking by the spouse (Tables 1 and 2). The first major study on involuntary smoking and lung cancer was reported by Hirayama in 1981 (Table 1). Hirayama conducted a cohort study of 91,540 nonsmoking women in Japan. Mortality in these women was assessed over a 14-year follow-up period. The ratio of the observed to expected numbers of lung cancer deaths increased in a statistically significant pattern with the amount smoked by the husbands. The findings could not be explained by other factors, such as age and occupation of the husband, and were unchanged when the follow-up was extended by several years (Hirayama 1984). After its publication, this article received intensive scrutiny, and correspondence in the British Medical Journal, which had published it, raised concern about various aspects of the study's methods and findings. In his responses to the correspondence, Hirayama satisfactorily answered most of these criticisms, although he could not eliminate the possibility of unreported smoking by women classified as nonsmokers. If self- reported nonsmokers married to smokers were more likely to actually be smokers, than the resulting bias would tend to indicate an increased risk from marriage to a smoker. Based on the same population, Hirayama has also reported significantly increased risk of lung cancer for nonsmoking married men whose wives smoke (Hirayama 1984).

In 1981, Trichopoulos and coworkers (1981) also reported increased lung cancer risk in nonsmoking women married to cigarette smokers (Table 2). These investigators conducted a case-control study in Athens, Greece, that included selected histological types of lung cancer and control subjects ascertained at a hospital for orthopedic disorders. The finding of increased risk was unchanged when the case and control series were enlarged (Trichopoulos et al. 1983).

The results of subsequently reported case-control studies have also demonstrated significantly increased risk of lung cancer in nonsmokers exposed to environmental tobacco smoke (Table 2). The findings from the more recent reports based on studies throughout the world greatly strengthen the evidence from the earlier studies. Several of the newer studies included relatively large numbers of nonsmokers (Garfinkel et al. 1985; Akiba et al. 1986; Dalager et al. 1986; Lam et al. 1987; Gao et al. 1987). Furthermore, in most of the newer studies, involuntary smoking was assessed in greater detail than in the earlier reports.

The results of two other investigations have also been interpreted as showing an increased lung cancer risk associated

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with involuntary smoking, but both studies have limitations. Knoth and coworkers (1983), in Germany, described 59 lung cancer cases in females of whom 39 were nonsmokers. Based on census data, these investigators projected that a much greater than expected proportion of the nonsmokers had lived in households with smokers. In another report, Gillis et al. (1984) described the preliminary results of a cohort study of 16,171 males and females in western Scotland (Table 1); exposure to tobacco smoke in the home increased the lung cancer risk for nonsmoking men but not for nonsmoking women. This observation was based on only 16 cases of lung cancer in nonsmokers, however.

Other investigations indicate lesser or no effects of exposure to environmental tobacco smoke on lung cancer risk (Tables 1 and 2). In these studies, however, the statistical uncertainty is large because of the relatively small numbers of subjects; accordingly, the apparently negative findings are statistically compatible with the findings of those studies judged as positive. Two separate case-control studies in Hong Kong, where lung cancer incidence rates in females are particularly high, did not indicate excess risk from involuntary smoking (Chan et al. 1979; Chan and Fung 1982; Koo et al. 1984; Koo et al. 1985; Koo et al. 1987). In the more recent of the two studies, the investigators comprehensively assessed cumulative exposure from home and workplace sources, but misclassification of exposure may have biased towards the negative results. A subsequent study in Hong Kong did find a significant association of spouse smoking and lung cancer risk (Lam et al. 1987). Lee and coworkers (Lee et al. 1986) in England reported a small case-control study with negative findings. Another recent hospital-based case-control study, conducted in Japan, also did not show an association between lung cancer risk and spouse smoking (Shimizu et al. 1988).

The results of the American Cancer Society's cohort study of lung cancer mortality in 176,139 nonsmoking women have also been considered by many as not showing an increased risk in those participants married to smokers (Garfinkel 1981). However, the risks for the nonsmoking women with smoking husbands were increased somewhat, but the increase was not statistically significant. Misclassification of exposure from active and involuntary smoking may have affected the results of this study. Preliminary results from a nationwide case-control study also did not demonstrate increased lung cancer risk from domestic exposure to tobacco smoke (Kabat and Wynder 1984), but the number of subjects was small. Two case-control studies of nonsmokers and smokers with selected histological types of lung cancer did not provide strong evidence for increased risk from involuntary smoking (Wu et al. 1985; Brownson et al. 1987). Both studies, however, included only small numbers of nonsmokers.

Conclusions on Involuntary Smoking and Lung Cancer

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Scientists draw on a wide range of evidence in judging whether an agent, such as environmental tobacco smoke, causes disease. In addition to epidemiological data, the findings of laboratory studies involving in vitro systems and of animal studies involving exposure to the agent are often relevant. Criteria have been developed for guidance in making judgments on the causality of exposure-disease relationships, but these criteria only provide guidelines, not strict rules of evidence (U.S. PHS 1964; Rothman 1986). Interpretation of the evidence on particular exposure-disease relationships often requires review by multidisciplinary panels of scientists who are instructed to reach a consensus, often in the setting of substantial uncertainty. For example, the World Health Organization regularly convenes panels of scientists to address the carcinogenicity of environmental agents.

For environmental tobacco smoke and lung cancer, the evidence has been considered by scientists convened by the International Agency for Research on Cancer of the World Health Organization, the National Research Council, and the U.S. Surgeon General (Table 3). All three groups concluded that environmental tobacco smoke causes lung cancer among nonsmokers, although the approach used by each group was unique. Consensus among the three groups, in spite of differing methodology, strengthens the determination that involuntary smoking causes lung cancer.

The International Agency for Research on Cancer of the World Health Organization (1986) reviewed the evidence available through the end of 1984. It reached its conclusion concerning involuntary smoking and lung cancer largely on the basis of biological plausibility. The agency cited the characteristics of sidestream and mainstream smoke, the absorption of tobacco smoke materials during involuntary smoking, and the nature of dose-response relationships for carcinogenesis, which project some risk for any level of exposure.

In reaching its conclusion, the National Research Council committee considered the biological plausibility of an association between environmental tobacco smoke exposure and lung cancer and the supporting epidemiological evidence, available through mid-1986. The committee carefully considered the sources of bias that may have affected the epidemiological studies and concluded that the association documented in the studies could not be attributed solely to bias. Based on a pooled analysis of the epidemiological data and adjustment for bias, the report's authors concluded that the best estimate for the excess risk of lung cancer in nonsmokers married to smokers was 25%.

The 1986 report of the U.S. Surgeon General also characterized involuntary smoking as a cause of lung cancer in nonsmokers. This conclusion was based on the extensive information already

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available on the carcinogenicity of active smoking, on the qualitative similarities between environmental tobacco smoke and mainstream smoke, and on the epidemiolgic data on involuntary smoking.

The extent of the lung cancer hazard associated with involuntary smoking in the United States remains uncertain, however (U.S. DHHS 1986; Weiss 1986). The epidemiological studies provide varying and imprecise measures of the risk (Tables 1 and 2), and exposures to environmental tobacco smoke have not been characterized for large and representative population samples. Thus, any risk assessments for involuntary smoking and lung cancer are subject to substantial uncertainty. Nevertheless, risk assessment can provide insight into the magnitude of the lung cancer problem posed by involuntary smoking.

Repace and Lowrey (1985) used data on lung cancer mortality in Seventh Day Adventists, a nonsmoking group, to estimate the effect of exposure to environmental tobacco smoke in increasing lung cancer risk. Their analysis lead to an estimate of 4,666 lung cancer deaths per year attributable to environmental tobacco smoke exposure. An appendix to the National Research Council's 1986 report provides estimates of the numbers of attributable lung deaths. For the year 1985, the risk assessment projects approximately 1,000 lung cancer deaths in males and 2,000 to 3,000 lung cancer deaths in females attributable to environmental tobacco smoke. Wells (1988) attributed 3,000 lung cancer cases annually in the U.S. to involuntary smoking.

Further epidemiological studies of involuntary smoking and lung cancer are in progress. These studies should refine our understanding of exposure-response relationships for lung cancer and exposure to environmental tobacco smoke. Other investigations are addressing the characteristics and toxicity of environmetal tobacco smoke and patterns of exposure to environmental tobacco smoke. While the results of these new studies will provide needed information for scientific purposes, the available data and the conclusions of the scientific community already provide a compelling rationale for reducing involuntary exposure to environmental tobacco smoke.

Involuntary Smoking and Cancer at Sites Other Than the Lung

Several reports have suggested that exposure to environmental tobacco smoke may increase risk of cancer at sites other than the lung. One study found that in children, maternal exposure to environmental tobacco smoke during pregnancy was associated with increased risk of brain tumors (Preston-Martin et al. 1982), and in another study paternal but not maternal smoking increased the risk of childhood rhabdomyosarcoma, a cancer of the soft tissues (Grufferman et al. 1982). In adults, involuntary smoking has been linked to a generally increased risk of malignancy (Miller

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1984) and to excess risk at specific sites.

Sandler and colleagues (Sandler, Everson, and Wilcox 1985a; 1985b; Sandler, Wilcox, and Everson 1985) conducted a case-control study on the effects of exposures to environmental tobacco smoke during childhood and adulthood on the risk of cancer. The cases included cancers of all types other than usual forms of skin cancer. For all sites combined, a statistically significant increase in risk was found for exposure to smoking by a parent (crude relative risk = 1.6) and by a spouse (crude relative risk = 1.5); the effects of these two sources of exposure were independent (Sandler, Wilcox, and Everson 1985). Statistically significant associations were found for some individual sites as well. These provocative findings will require replication in additional studies. In a case-control study, such as reported by Sandler and colleagues, biased information on exposure to environmental tobacco smoke is of particular concern. In the cohort study in Japan, Hirayama (1984) found significantly increased mortality from nasal sinus cancers and from brain tumors in nonsmoking women married to smokers. In a case-control study of bladder cancer, involuntary smoking at home and at work did not increase risk (Kabat et al. 1986). Cervical cancer, which has been linked to active smoking, was associated with duration of involuntary smoking in a case-control study in Utah (Slattery et al. 1989).

These associations of involuntary smoking with cancer at diverse sites other than the lung cannot be readily supported with arguments for biological plausibility. Increased risks at some of the sites, e.g., cancer of the nasal sinus and female breast cancer, have not been found in active smokers (U.S. DHHS 1982). In fact, the International Agency for Research on Cancer (1986) has concluded that effects would not be produced in involuntary smokers that would not be produced to a larger extent in active smokers.

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FIGURES AND TABLES, CHAPTER 4

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TABLE 1

Cohort Studies of Involuntary Smoking and Lung Cancer

Study	Findings	Comments
91,540 nonsmoking females, 1966-1981, Japan (Hirayama 1981).	Age-occupation adjusted RR* by husbands' smoking: Nonsmokers - 1.00† Exsmokers - 1.36 Current smokers < 20/day - 1.45 ≥ 20/day - 1.91	Trend statistically significant. All histological types of lung cancer.
176,139 nonsmoking females, 1960-1972, U.S. (Garfinkel 1981).	Age-adjusted RR by husbands' smoking: Nonsmokers - 1.00† Current smokers < 20/day - 1.27 ≥ 20/day - 1.10	All histologies. Effect of husbands' smoking not statistically significant.
8,128 males and females, 1972-1982, Scotland (Gillis et al. 1984).	Age-adjusted RR for exposure to a tobacco smoker in the home: Males - 3.25 Females - 1.00	Preliminary, small numbers of cases.

*RR = relative risk, as estimated by the ratio of observed to expected number of lung cancer deaths.

†Reference category, risk arbitrarily set to unity as the reference point for comparison.

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TABLE 2

Case-control Studies of Involuntary Smoking and Lung Cancer

Study	Findings	Comments
40 nonsmoking female cases, 149 controls, 1978-1980, Greece (Trichopoulos et al. 1981).	RR* by husband smoking: Nonsmokers - 1.0 Exsmokers - 1.8 Current smokers < 20/day - 2.4 ≥ 20/day - 3.4	Trend statistically significantly. Histologies other than adenocarcinoma and bronchioloalveolar carcinoma.
84 female cases and 139 controls, 1976-1977, Hong Kong (Chan et al. 1979; Chan and Fung 1982).	RR of 0.75 associated with smoking spouse, compared to 1.0 for a nonsmoking spouse.	All histologies. Two reports are inconsistent on the exposure variable.
22 female and 8 male nonsmoking cases, 133 female and 180 male controls, U.S. (Correa et al. 1983).	RR by spouse smoking: Nonsmokers - 1.00 < 40 pack years - 1.48 ≥ 41 pack years - 3.11	Significant increase for ≥ 41 pack years. Bronchioloalveolar carcinoma excluded.
19 male and 94 female nonsmoking cases, and 110 male and 270 female nonsmoking controls, Japan (Akiba et al. 1986).	For females, RR of 1.5 if husband smoked; for males, RR of 1.8 if wife smoked.	Clinical or radiological diagnosis for 43%. All types of lung cancer.
99 nonsmoking cases and 736 controls, Louisiana, Texas, New Jersey (Dalager et al 1986).	RR for marriage to a marriage to a smoking spouse was 1.5.	Nearly 100% histological confirmation. All types of lung cancer.
28 nonsmoking cases and 292 nonsmoking controls, New Mexico (Humble et al. 1987).	RR for marriage to a smoking spouse was 3.2 No effect in active smokers.	All types other other than bronchioloalveolar carcinoma.
77 nonsmoking cases, 2 matched control series, Sweden (Pershagen et al. 1987).	RR for marriage to a smoker was 3.3 for squamous small cell carcinomas.	No effect of exposure for other types. Study based within a cohort.

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TABLE 2 (continued)

Case-control Studies of Involuntary Smoking and Lung Cancer

Study	Findings	Comments
102 adenocarcinoma cases, 50 males and 52 females, and 131 controls, Colorado (Brownson et al. 1987).	No effect in entire group. In nonsmoking women, RR of 1.7 for exposure $\geq$ 4 hrs/day, versus 1.0 for $\leq$ 3 hrs/day.	Involuntary smoking effect not significant in nonsmoking women, but only 19 such cases included.
25 male and 53 female nonsmoking cases with matched controls, 1971-1980, U.S. (Kabat and Wynder 1984).	RR not significantly increased for current exposure at home: Males - 1.26 Females - 0.92	All types. Findings negative for spouse smoking variable as well.
88 nonsmoking female cases, 1981-1982, Hong Kong (Koo et al. 1984; Koo et al. 1985).	RR of 1.24 (not statistically significant) for combined home and workplace exposure versus 1.0 for nonexposed. No association with cumulative hours of exposure.	All types of lung cancer.
31 nonsmoking and 189 smoking female cases, U.S. (Wu et al. 1985).	No significant effects of exposure from parents, spouse, or workplace in smokers and nonsmokers.	Adenocarcinoma and squamous cell carcinoma only.
134 nonsmoking female cases, U.S. (Garfinkel et al. 1985).	Nonsignificant RR of 1.22 if husband smoked. Significantly increased RR of 2.11 if husband smoked 20 or more cigarettes daily at home. Significant trend of RR with number of cigarettes smoked at home by the husband.	All types of lung cancer. Careful exclusion of smokers from the case group.
15 male and 32 female nonsmoking cases, and 30 male and 66 female nonsmoking controls, England (Lee et al. 1986).	Overall RR for spouse smoking of 1.1.	Hospital-based study.

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TABLE 2 (continued)

Case-control Studies of Involuntary Smoking and Lung Cancer

Study	Findings	Comments
199 never smoking female cases and 335 controls (Lam et al. 1987).	Overall odds ratio = 1.7, significantly increased for marriage to a smoker. Odds ratio = 2.1 for adenocarcinoma.	All histologies. No evidence for exposure-response.
246 nonsmoking female cases and 375 controls, Shanghai (Gao et al. 1987).	Overall odds ratio = 0.9 for ever living with a smoker. Risk increased with duration of living with a smoking husband.	All histologies, but majority adenocarcinoma. No effect of childhood exposure.
90 nonsmoking female cases and 163 controls, Japan (Shimizu et al. 1988).	Odds ratio for husbands' smoking was 1.1. No effect of exposure at work.	All histologies. Increased risk from other household members' smoking.
28 smoking female cases and 62 controls, Japan (Inoue and Hirayama 1988).	Overall odds ratio = 2.3 for marriage to a smoker.	Risk increased with the number of cigarettes smoked by the husband.
54 nonsmoking female cases and 93 controls, Tianjin, China (Geng et al. 1988).	Overall odds ratio = 2.2 for marriage to a smoker.	All histologies.

*RR = relative risk as estimated by the odds ratio.

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TABLE 3

Conclusions of the World Health Organization,
National Research Council and U.S. Surgeon General
on Involuntary Smoking and Lung Cancer

World Health Organization
"Knowledge of the nature of sidestream and mainstream smoke, of the materials absorbed during "passive" smoking, and of the quantitative relationships between dose and effect that are commonly observed from exposure to carcinogens, however, leads to the conclusion that passive smoking gives rise to some risk of cancer."
National Research Council
"The weight of evidence derived from epidemiologic studies shows an association between ETS exposure of nonsmokers and lung cancer that, taken as a whole, is unlikely to be due to chance or systematic bias. The observed estimate of increased risk is 34%, largely for spouses of smokers compared with spouses of nonsmokers."
U.S. Surgeon General
"Involuntary smoking can cause lung cancer in nonsmokers." "The absence of a threshold for respiratory carcinogenesis in active smoking, the presence of the same carcinogens in mainstream and sidestream smoke, the demonstrated uptake of tobacco smoke constituents by involuntary smokers, and the demonstration of an increased lung cancer risk in some populations with exposures to ETS leads to the conclusion that involuntary smoking is a cause of lung cancer."

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CHAPTER 5

MEASURING EXPOSURE TO ENVIRONMENTAL TOBACCO SMOKE

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INTRODUCTION

Assessing exposure to ETS can be done by direct and indirect methods. Direct assessment of exposure includes the use of biomarkers and personal air monitoring. Indirect methods include use of questionnaires and modeling. Modeling is based upon measurement of air contaminant concentrations in enclosed spaces, the factors controlling the concentrations and an assessment of the time people spend in those spaces. Direct assessment of exposure includes the use of biomarkers and personal air monitoring.

In recent years there has been a growing interest in the analysis of physiological fluids for specific compounds that are indicative of exposure to ETS. Thiocyanate (1), carboxyhemlobin (2), nicotine and cotinine (3), hydroprloine (4), N-Nitrosoproline (5), aromatic amines (6), genotoxicity (7) and protein or DNA adducts (8) measurements in physiological fluids have all been considered as indicators of exposure to either active or passive tobacco smoke. while these biomarkers are indicative of exposure they may not be directly related to potential for development of the adverse effect under study and can show considerable variability from individual to individual sue to differences in uptake, distribution and metabolism. Some of these markers may not be specific to ETS exposure (e.g., carboxyhemoglobin) while others (e.g., thiocyanate) may be useful for active smoke exposure but not sensitive enough for ETS exposures. Biomarkers are indicators of exposure not measures of dose. Cotinine and nicotine measures in the blood, urine and saliva have been widely used as indicators of exposure to ETS (e.g. g) and are valuable in determine total or integrated exposure to ETS across all environments that na individual spends his time. A biomarker of exposure however, does not provide an exact measure of ETS exposure in any one environment of provide information on the environmental factors impacting the

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concentration in the environments that people spend their time.

Personal air monitoring employs samples (worn by individuals) that record the integrated concentration of a contaminant individuals are exposed to in the course of their normal activity for time periods of several hours to several days. The monitors can be active (employing pumps to collect and concentrate the air contaminant) or passive (working on the principal of diffusion). As with biomarkers personal monitoring provides an integrated measure of exposure to an individual air contaminant across a number of environments in which the individual spends time. It provides no individual environments.

Questionnaires have been used extensively in epidemiologic studies for the classification of individuals into broad categories of ETS exposure based upon self reports of exposure. Questionnaires are also used to obtain information on the physical environments in which exposures take place and the factors affecting the exposures in those environments (volume, number of cigarettes, etc.) as well as the amount of time people spend in those environments. Questionnaires are an indirect measure of exposure and as such cannot provide information on specific levels.

The modeling approach employs the use of stationary monitors (active or passive) to measure ETS associated air contaminant concentrations in a number of spaces (microenvironments). These measured concentrations are then combined with time activity patterns (time budgets) to determine the average exposure of an individual as the sum of the concentrations in each environment weighed by the time spent in that environment. When the air sampling data for a given space is combined with information concerning the factors controlling the contaminant concentrations in the space (ventilation , mixing, number of cigarettes smoked, etc) models can be developed and validated to predict concentration sin occupied spaces where sampling data goes not exist. It is this modeling approach which is used in Chapter 7 of this report.

Critical to assessing total exposure to ETS either through personal air monitoring or through modeling is the method of air contaminant monitoring used. This chapter will present a discussion of the issues to be considered in air sampling for ETS with emphasis on air sampling in enclosed spaces rather than on personal monitoring. Selection of ETS contaminants to be monitored, available methods of sample collection and analysis, operating principals for each method, relative advantages and disadvantages of each method and sources for purchase of sampling equipment will be covered.

SELECTION OF ETS CONTAMINANTS FOR MONITORING

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Environmental tobacco smoke (ETS) is a complex mix of over 4,000 air contaminants found in both the vapor and particle phase. Some of the ETS contaminants are associated solely with the combustion of tobacco (e.g. nicotine and tobacco specific nitrosimines) while others are emitted by a number of other sources in the outdoor and indoor environment (e.g. carbon monoxide and respirable suspended particles). Given this complex mix it is necessary to identify an air contaminant or class of air contaminants for monitoring that would be indicative of the presence and amount of ETS in an indoor space. Such a contaminant or class of contaminants are called tracer, marker or proxy compounds.

The appropriateness or usefulness of a marker compound for the identification and quantification of ETS in indoor environments is evaluated by the following five criteria:

1.the marker compound would be unique or nearly unique to the tobacco so that other outdoor or indoor sources are small in comparison,

2.the marker compound should be in present in sufficient quantity in the tobacco such that when it is emitted it will be in room air concentrations that can be easily detected even when the smoking rates are low,

3.the emission rate for the compound should be similar for a variety of tobacco products,

4.a fairly consistent ration of the marker compound(s) to individual contaminants of interest or categories of contaminants (e.g., suspended particulates) should exist under a range of environmental conditions for a variety of tobacco produces,

5.measurement methods for monitoring the marker compound would be available which will permit the assessment of concentrations of the marker compound in indoor spaces or personal exposure levels in an easy, accurate and cost effective manner.

The first four criteria are listed in the NAS report on ETS (9). It should be clearly stated that the above criteria for selecting a suitable marker compound are the ideal criteria and that it practice no single contaminant or class of contaminants have been identified which meet all the criteria. There is in fact no single marker which is universally accepted or recognized as representing ETS. Selection of a suitable marker for ETS reduces to satisfying as many of the criteria as is practical and recognizing the limitations of the selected marker compound.

Over the last several years several marker air contaminants have been used to represent ETS concentrations in both chamber

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studies and in a number of microenvironments where people spent their time. Carbon monoxide, nitrogen oxides, acrolein, benzene, toluene, tobacco specific nitrosamines, vapor and particle phase nicotine, isoprene, pyridine, particle phase nicotine and cotinine, respirable suspended particles, polonium-210 and benzo[a]pyrene are among the many air contaminants that have been used or proposed for use as indicators of the presence of ETS. Tables in chapter 6 show the range of concentrations measured in a number of indoor environments were smoking occurred. All the markers used to date have some problems associated with their use, for example, carbon monoxide, nitrogen oxides, etc. have many indoor and outdoor sources other than the combustion of tobacco, while such compound as nitrosamines, benzo[a]pyrene, etc. are sufficiently difficult to measure (concentration sin smoking environments are low, cost of collection and analysis of samples, etc.) such that their use is very limited.

At the present time respirable suspended particulate matter (RSP) and vapor phase nicotine are widely and most commonly used as markers of the presence and concentration of ETS for a variety of reasons associated with their ease of measurement, existing knowledge on their emission from tobacco combustion and their relationship to other ETS contaminants. This chapter will focus on the use of RSP and nicotine as markers for ETS and the methods available for their measurement in indoor environments.

The use of RSP as a marker for ETS is based upon information obtained from a number of chamber and field studies and available air sampling methodology (9, 10), including the following:

1.Tobacco combustion has a major impact on the mass of suspended particle matter in occupied spaces in the size range of ,2.5 um (respirable suspended particle mass - RSP) (9, 10). RSP is a major component of ETS and is detectable above background levels in occupied environments even under conditions of low smoking rates (see Chapters 6 & 7 of this report).

2.RSP contains a number of the tobacco related compounds of health concern.

3.RSP emissions are major component of the air contaminants emitted into the environment from tobacco combustion with relatively little variation in emissions across different brands of cigarettes when considered on a gram of tobacco consumes bases.

4. A number of methods are available to accurately and inexpensively measure RSP levels on a short-term (minutes) or long-term (hours) integrated bases with minimal expense.

5.There are outdoor particle health standards established by the U.S. Environmental Protection Agency (EPA) which provide a

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frame of reference in interpreting measured RSP levels associated with ETS. The EPA standard is for particle mass, 10 um.

The major drawbacks in using RSP as a marker for ETS are the following:

1.RSP encompasses a broad range of particles of varying chemical composition and size emanating from a number of sources both outdoors and indoors and as such is not unique to ETS.

2.background levels of RSP, form other sources, in inclosed spaces has to be determined in order to assess the contribution of ETS.

3.the ratio of specific ETS vapor or particle phase air contaminants of health concern to RSP in ETS is not known.

Vapor phase nicotine has recently been the focus of research efforts to assess its use as marker for ETS in indoor environments. Nicotine like RSP exhibits many of the properties necessary to serve as a potential marker for ETS, including:

1.It is unique to tobacco smoke and is predominately in one phase.

2.Nicotine emissions are a major component of the air contaminant emissions emitted into the environment by tobacco combustion with relative little variability across brands of cigarettes when considered on a gram of tobacco consumed bases.

3.Nicotine has been easily measured in environments where smoking occurs even when the smoking rates are low.

4.Some recent field studies have bound a reasonably consistent RSP to vapor phase ration for ETS in the residential and non-industrial occupational environments (11, 12), suggesting that vapor phase nicotine, for some applications, may vary with ETS related RSP and this be used to estimate the RSP attributable to ETS.

5.A number of new sampling methods are available to accurately and inexpensively measure environmental nicotine levels.

6.Nicotine is one of the very few air contaminants associated with ETS for which sensitive biochemical measures of exposure exist (nicotine and cotinine in physiological fluids), thus providing a link between air concentrations of ETS and internal dose.

The major drawbacks in using vapor phase nicotine as a marker for ETS are the following:

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1.More information is needed on the variability of nicotine emissions from a variety of brands of cigarettes.

2.The ration of nicotine to other vapor phase and particle phase ETS constituents (including RSP) needs to be better evaluated under a range of environmental condition s(temperature, humidity, mixing, etc.) and in different environments.

3.There are no health standards controlling exposures to nicotine and nicotine has not been identified as a contaminant directly associated with adverse health or comfort effects, therefore nicotine concentration sin spaces should be interpreted with care.

MEASUREMENT OF RSP AND NICOTINE IN AIR

The measurement of RSP and vapor phase nicotine, as with any air contaminant, requires careful consideration of such factors as the spatial and temporal distribution of the contaminant in the spaces of interest, the time averaging measurement desirable, the physical and chemical characteristics of the contaminants and availability of accurate and relatively inexpensive measurement methods that are easy to use.

Concentrations of RSP, nicotine, and other ETS constituents in an enclosed space can exhibit a pronounced spatial and temporal distribution. The concentration is the result of a complex interaction of several important variables including: a) the generation rate of the contaminant(s) from the tobacco; b) the rate of tobacco consumption; c) the ventilation or infiltration rate; c) the concentration of the contaminant(s) in the ventilation or infiltration air; e) air mixing in the space; f) removal of contaminants by surfaces or chemical reactions; g) remission of contaminants by surfaces; and h) the effectiveness of any air cleaners that may be present. The location for obtaining a RSP or nicotine measurement in a space, time of sample collection and length of sample have to take into consideration the above factors.

Generally background concentrations of RSP (during no smoking in the space) is desirable because of other sources of RSP, particularly outdoor sources. Since nicotine is removed by indoor surfaces it might be useful to obtain background levels of nicotine in environments where smoking is heavy. Background levels of nicotine might also be indicative of outgassing from surfaces of other volatile ETS components.

Selection of the sampling location(s) will in large part be determined by the goal of the monitoring effort and available equipment. For example, it the goal is to assess concentrations in the general enclosed environment where smoking may be

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prohibited or restricted to given location(s) then representative location(s) should be selected for monitoring which would be indicative of the occupants exposure. Toward this end one or two samples in each location may be sufficient. This assumes that the contaminants in the space are reasonably well mixed. If the goal is to determine the exposure in the work station of an occupant who is concerned about his or her exposure then sampling near or at that persons work station is necessary. Frequently, there are severe limitations on the availability of air sampling equipment resources for the collection and analysis of collected air samples. Such situations require careful attention to the selection of a representative location for collection of samples.

The period of time over which a sample is collected can vary from as little as one minute to as much as two or more weeks depending on the sampling methods employed and the purpose of monitoring. The portable piezoelectric particle mass monitors provide short term RSP measurements over a 24 second or two minute period while passive nicotine monitors can provide integrated measurements from one day to over two weeks. Recording short-term measurements would necessitate several repeated measurements to insure the measurement of a representative concentration in the space since the ETS contaminants can vary considerably in time. Short-term measurements should also be accompanied by the recording of such information as the occupancy and smoker density to determine how representative the measurement would be of a variety of smoking rates that could be expected to be encountered in the space. Long-term measurements need to be interpreted in light of the actual time the spaces were occupied and time smoking occurred. Both short-term and long-term sampling of spaces is useful for a variety of purposes including concentration modeling of spaces, determining compliance with smoking policies, investigating ETS related complaints from occupants and determining exposures associated with health and comfort effects of ETS.

MEASUREMENT METHODS FOR RSP

ETS related and non-ETS related RSP encompasses a very broad range of particles of varying chemical composition and physical properties. In general terms RSP refers to particles less than 2.5 um with no distinction as to chemical composition or size distribution. Over the e=years there have been a large number of measurement methods developed to measure particles in the RSP size range. These methods have utilized the physical properties of the particles (impaction, light scattering, etc.) to obtain measurements ont he size distribution and mass of the particles in the RSP size range. These monitoring methods vary considerably interims of complexity, application and cost. The RSP sampling methods as with sampling methods for other air contaminants were developed for outdoor and workplace monitoring with relatively few instruments developed specifically for indoor

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applications. The discussion of measurement methods for RSP presented here will cover only those methods which have relatively wide application, as determined by cost, ease of use and accuracy, in measuring RSP in indoor spaces.

Table 1 presents a summary of the RSP measurement methods which are applicable for use in monitoring RSP levels indoors. The table lists the measurement method, sampling times, sampling rates, concentration range, accuracy, manufacturer and cost for each monitor as well as comments concerning the use of the monitor. Many of the instruments are gravimetric providing an integrated measure of particle mass concentrations over several hours to several days, while other systems utilize light scattering or piezoelectric resonance to provide a short-term measure of particle concentration. The gravimetric measurements require the weighing of filters before and after particle collection in a humidity and temperature controlled environment to determine the mass concentration. The gravimetric measurement also results in a particle mass sample which could, depending on the filter media use and handling and storage of the collected sample, be subjected to detailed chemical analysis to obtain additional source information. Gravimetric particle mass measurement methods are considered a standard method on particle measurement. The actual size distributions measured by the instruments vary considerably with the optical scattering instruments measuring a broad particle size range (0.1 - 10.0 um) while other monitoring systems (e.g. gravimetric methods) utilize cyclones or impactors to collect the mass of particles below 3.5 or 2.5 um. Only some of the monitors actually measure RSP, particles less than or equal to 2.5 um.

Selection of a method for monitoring RSP depends in large part on the purpose for taking the measurements. If the application calls for integrated particle mass measurements in spaces over a period of days with chemical analysis of filters then the integrated gravimetric measurements utilizing the Harvard or NBS samplers may be the methods of choice. These systems are not as portable as the other systems listed in Table 1. If six to twelve hour particle mass concentrations of spaces or personal samples (sampler worn by a subject) with possible subsequent filter analysis then the standard industrial hygiene personal pumps with particle preselectors may be the method of choice. In using any gravimetric method care must be taken to insure the sampling times are sufficient to collect adequate particle sample for accurate determination of mass concentrations. In addition, pump flow rates and filter selection and handling are important. If the sampling application calls for short-term measurements in one or several locations over variable time frames with lightweight portable equipment which is easy to use then the piezobalance or light scattering monitoring systems might be the methods of choice. It should be noted that all the methods listed in Table 1 have been used with good success in chamber and

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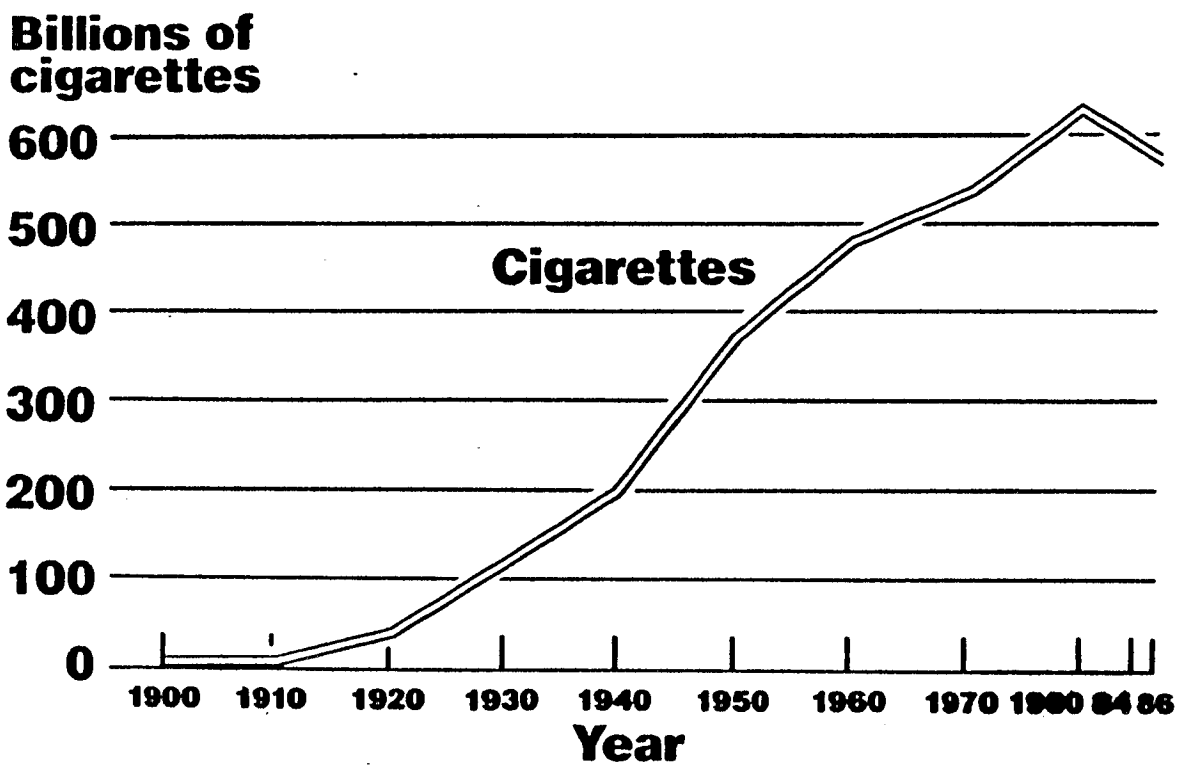
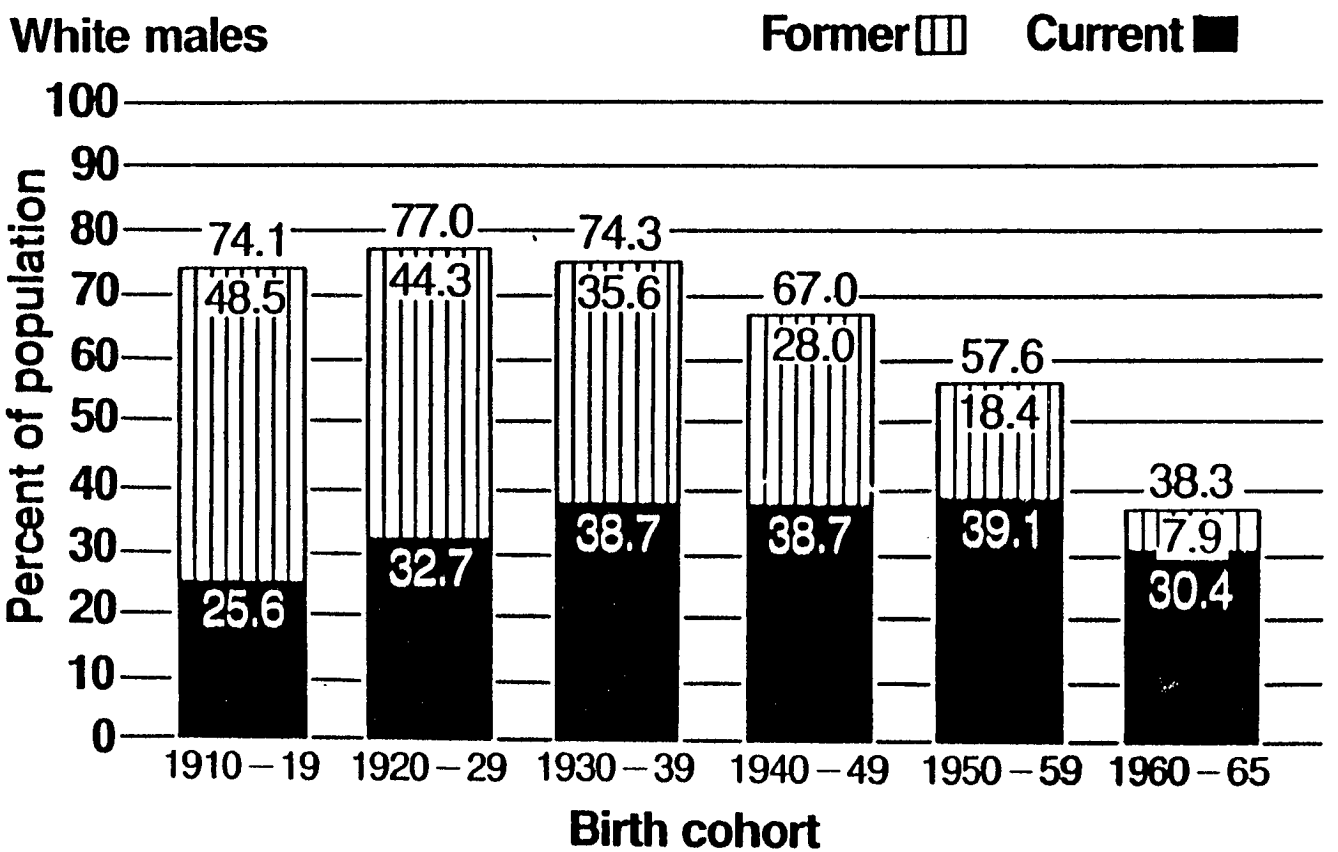
Cigarette consumption



Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

Lifetime prevalence of cigarette smoking by birth cohort



Source: National Health Interview Survey, 1983.

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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

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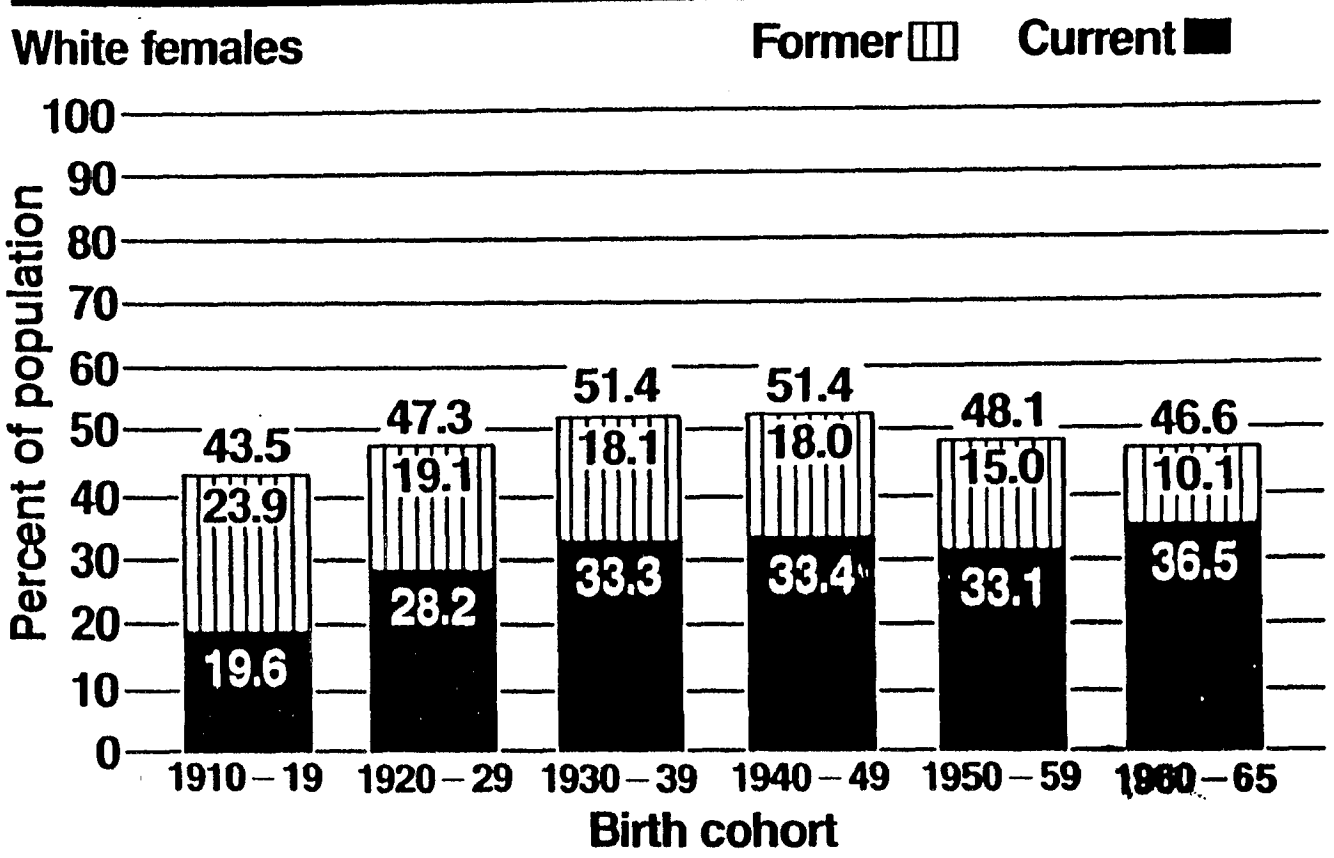
Lifetime prevalence of cigarette smoking by birth cohort

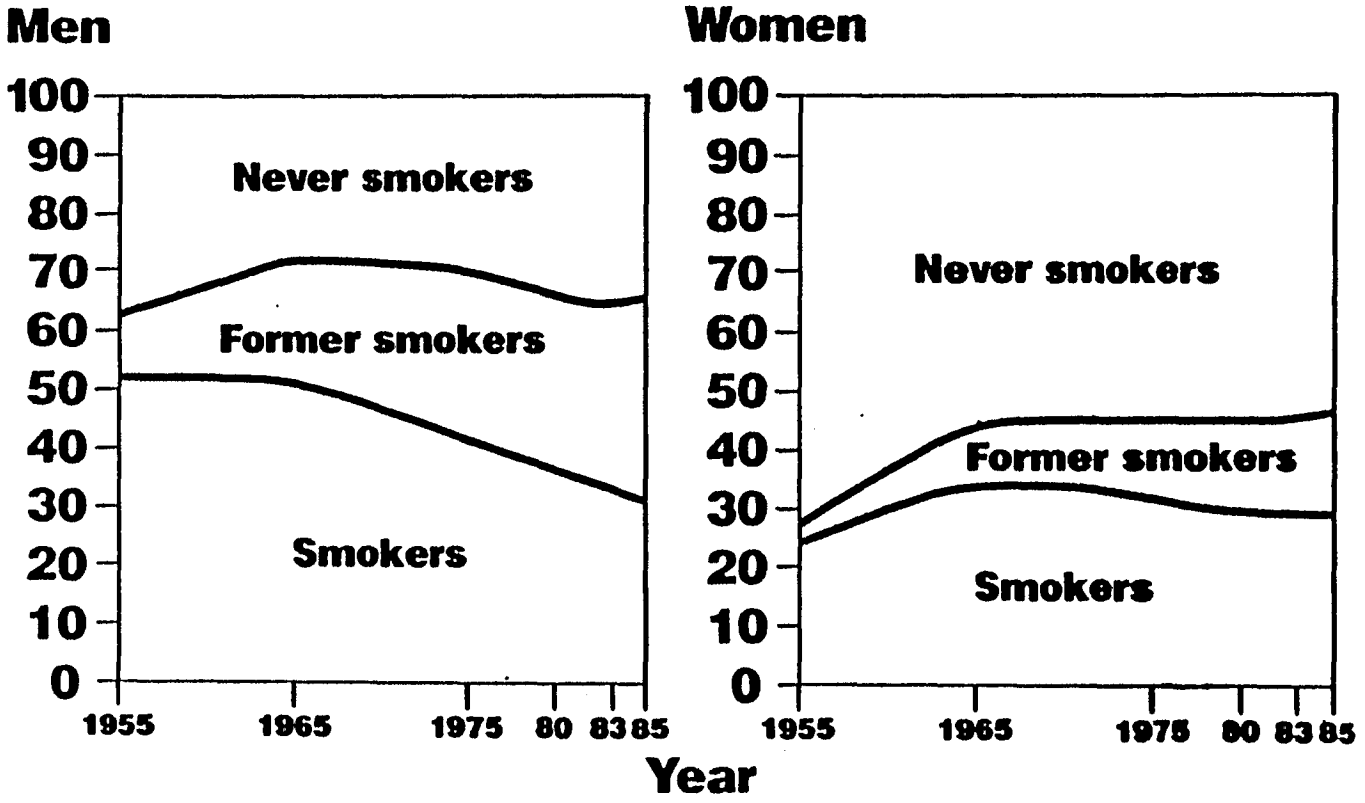


Source: National Health Interview Survey, 1983.

24 c

Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

Percentage of smokers and nonsmokers, 1955–1985



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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

Outline of Eight Major Prospective Studies

Authors	Doll Hill Peto Pike	Hammond	Dorn Kahn Rogot	Hirayama	Best Josie Walker	Hammond Horn	Weir Dunn Linden Breslow	Cederlof Friberg Hrubec Lorich
Subjects	British doctors	Males and females in 25 States	U.S. veterans	Total population of 29 health districts in Japan	Canadian pensioners	White males in nine states	California males in various occupations	Probability sample of the Swedish population
Population size Females	40,000 6,000	1,000,000 582,671	290,000 < 1%	265,000 142,857	92,000 14,000	187,000	68,000	55,000 27,700
Age Range	20-85+	35-84	35-84	40 and up	30-90	50-69	33-64	18-69
Year of enrollment	1951	1960	1954 1957	1966	1955	1952	1954	1963
Years of followup reported	20-22 years	12 years	16 years	13 years	6 years	4 years	5-8 years	10 years
Number of deaths	11,166	150,000	107,500	39,100	11,000	12,000	4,700	4,500
Person years of experience	800,000	8,000,000	3,500,000	3,000,000	500,000	670,000	480,000	550,000

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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

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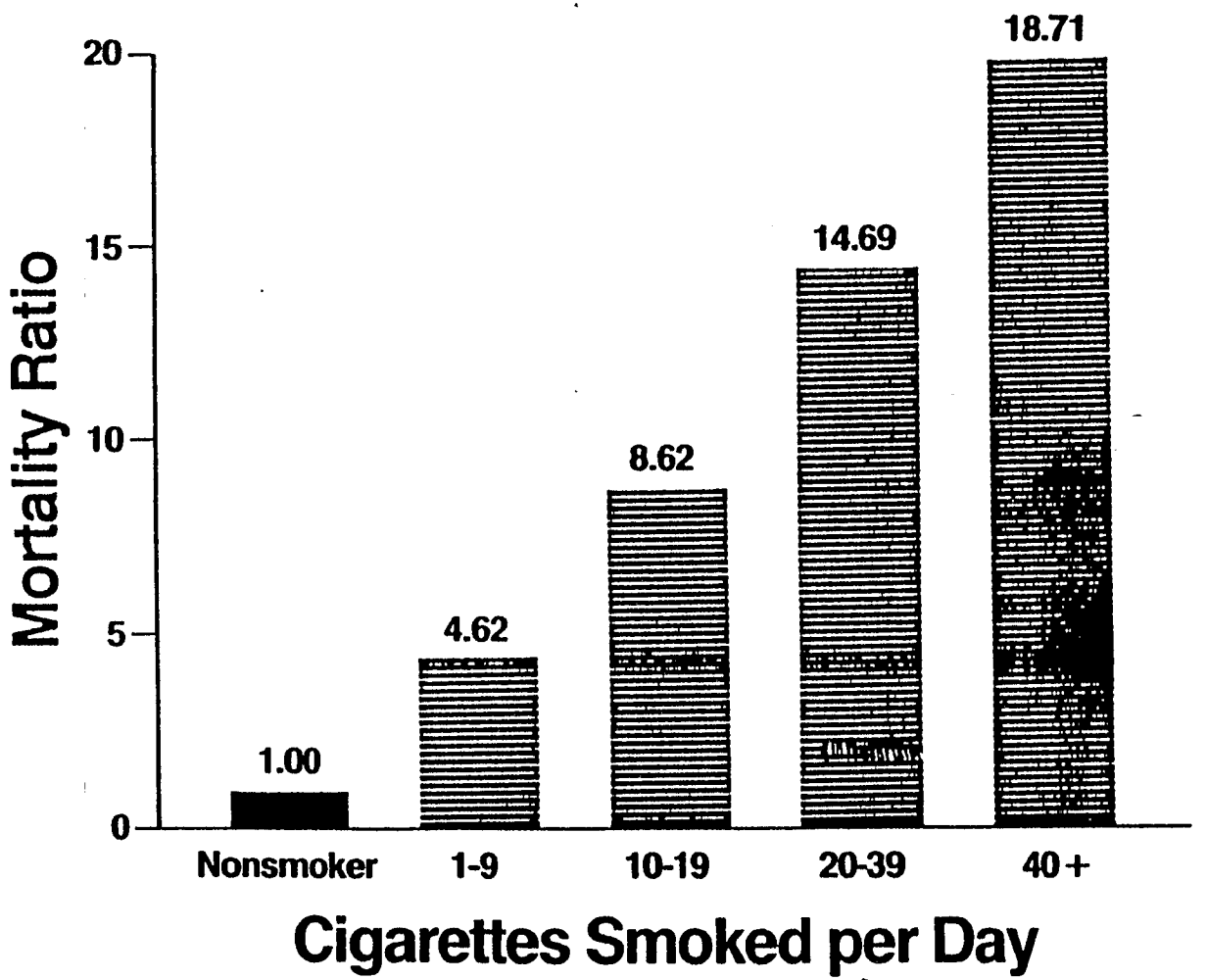
Lung cancer mortality ratios for men, by current number of cigarettes smoked per day—ACS 25 state study



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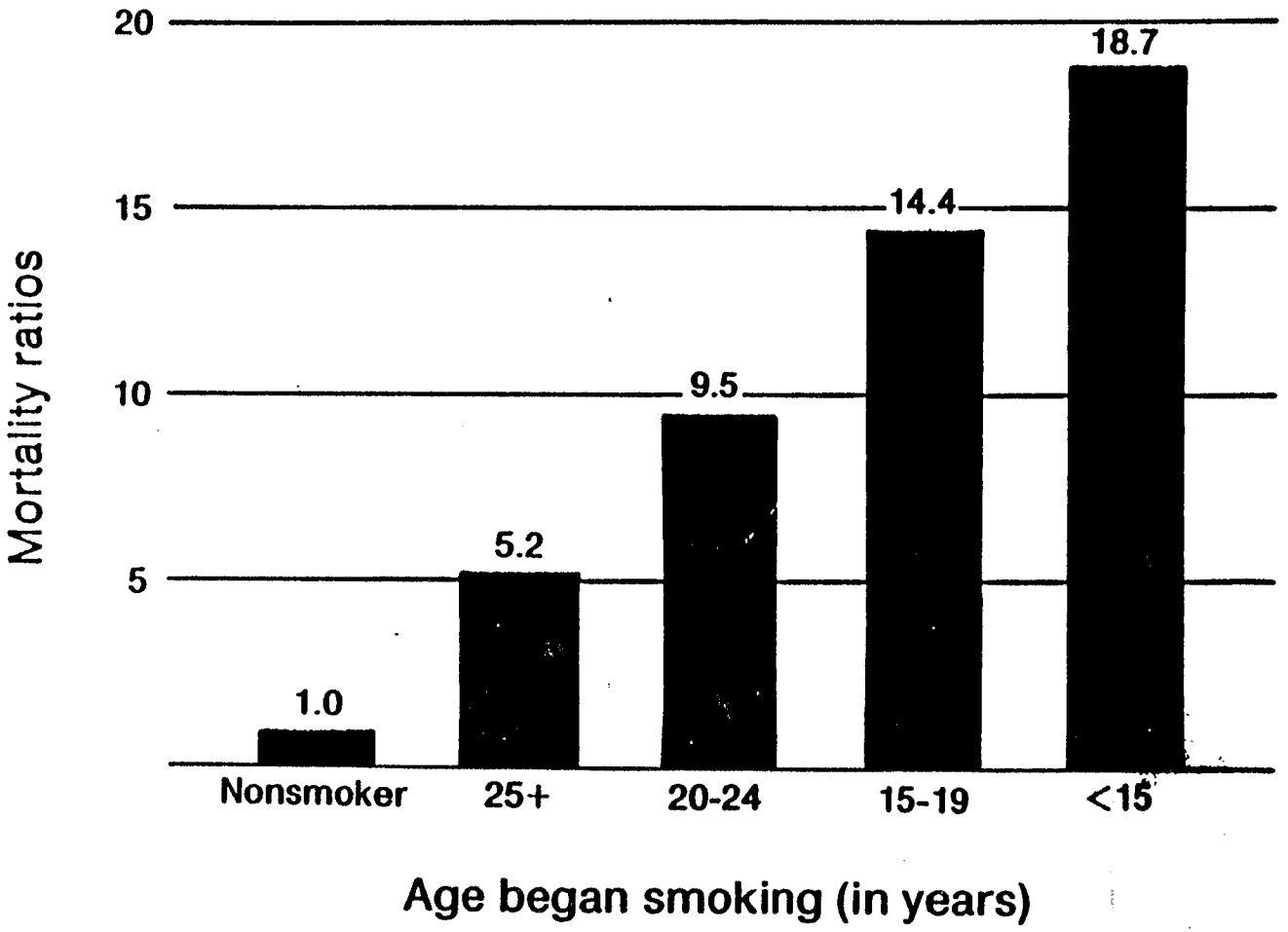
Lung cancer mortality ratios for males, by age began smoking — U.S. Veterans' Study



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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

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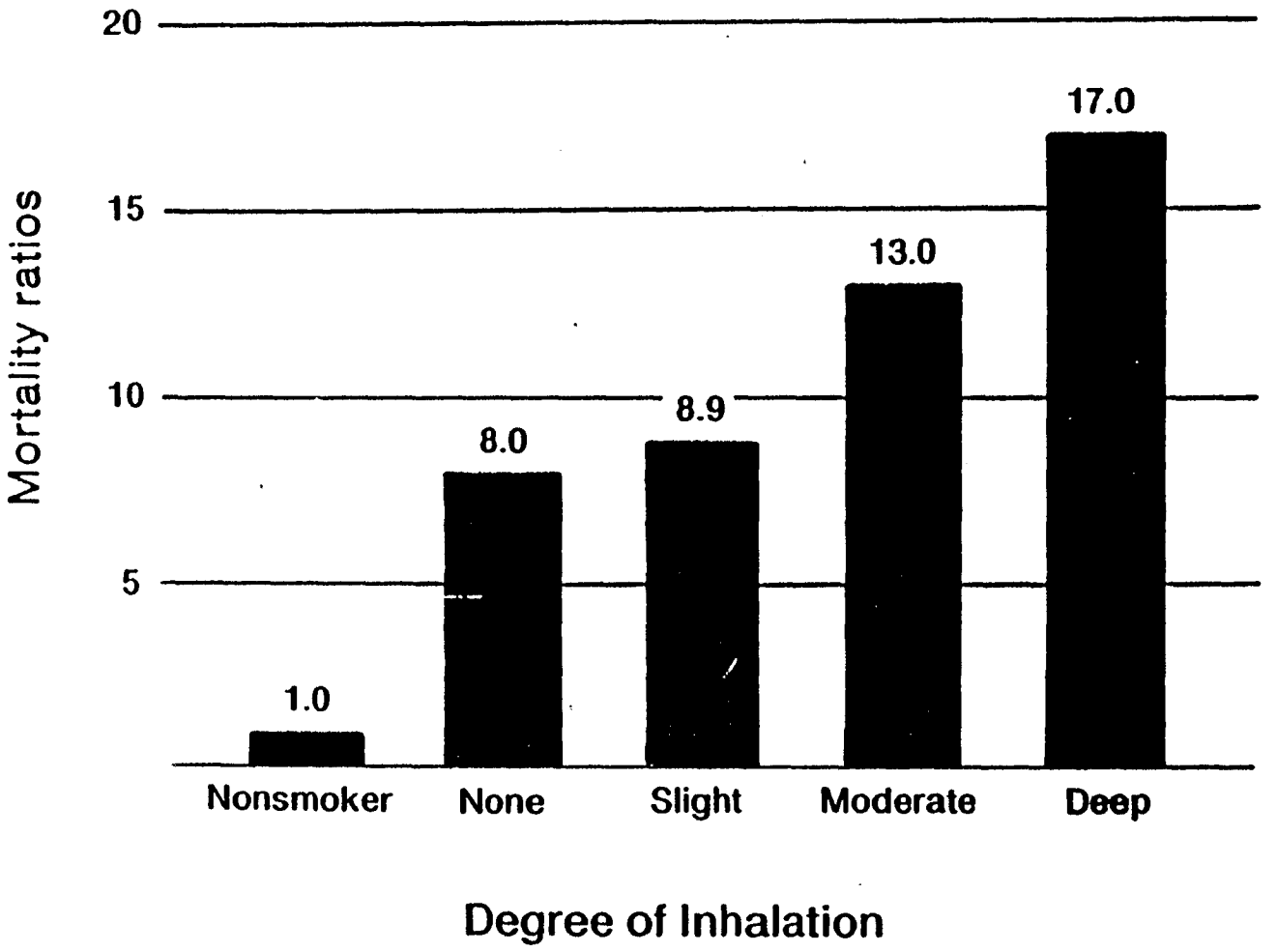
Lung cancer mortality ratios by degree of inhalation — ACS 25-State Study



24 h

Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

Lung cancer mortality ratios in ex-cigarette smokers, by number of years stopped smoking — British Physicians' Study

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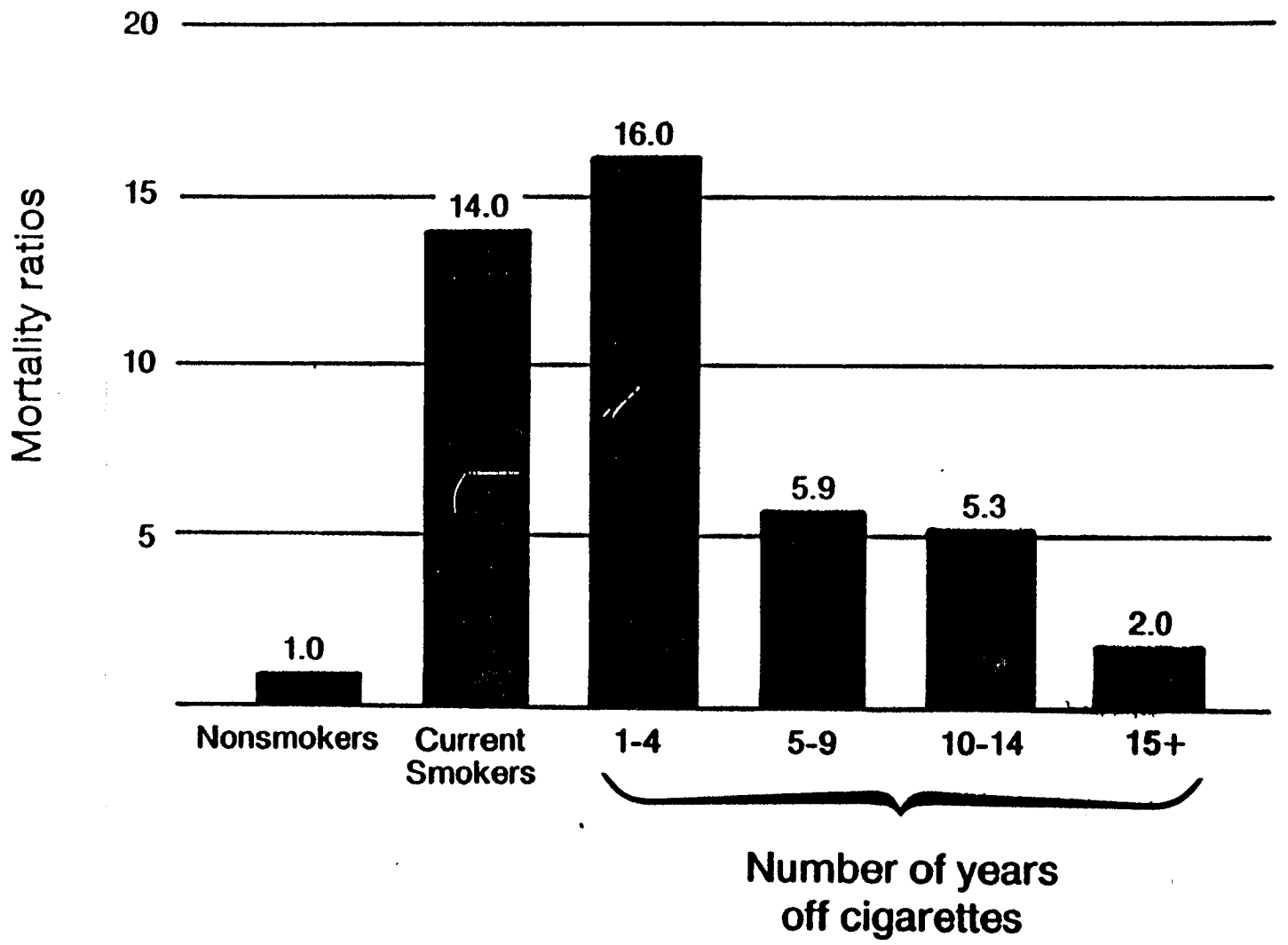

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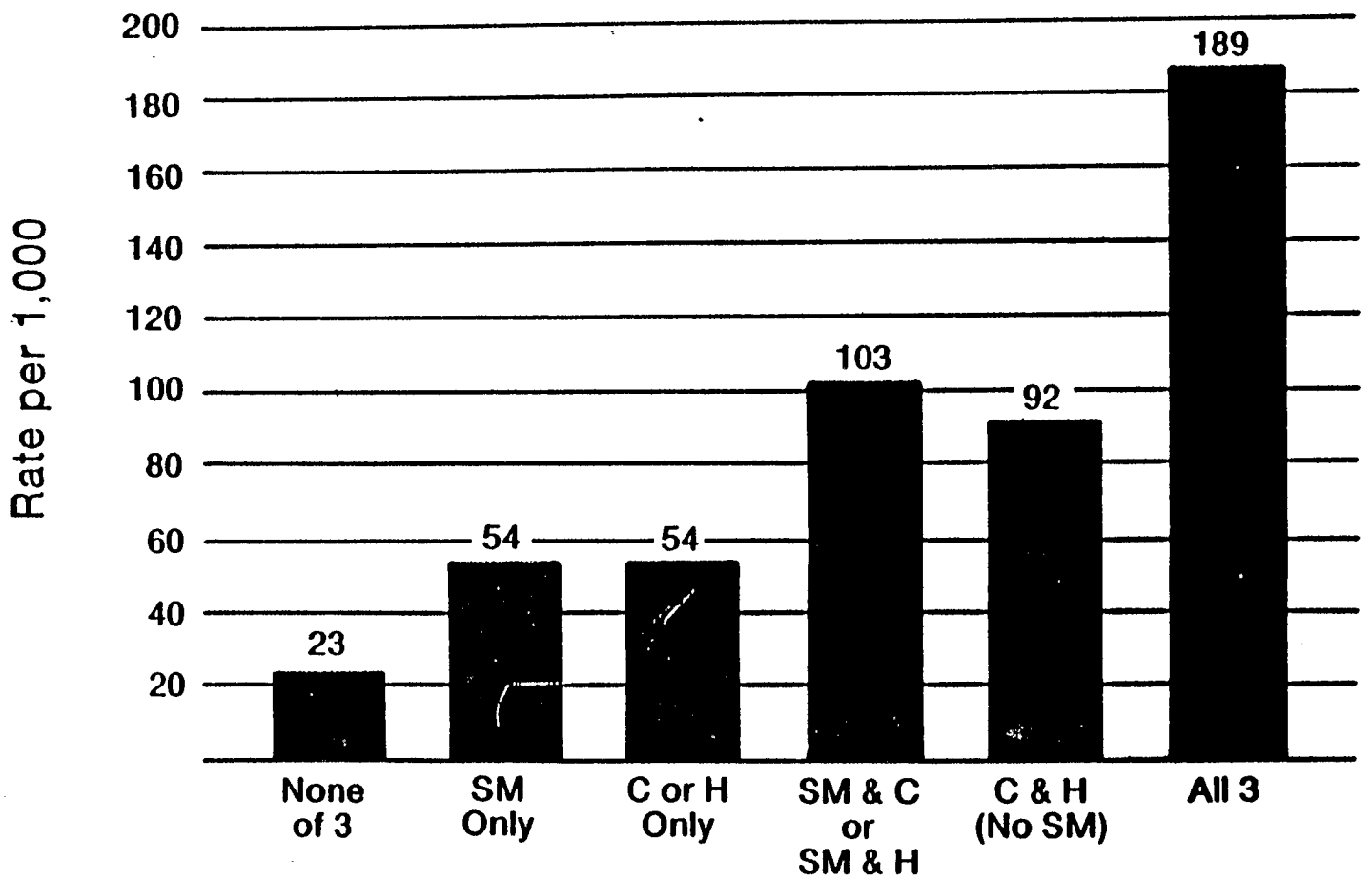
Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

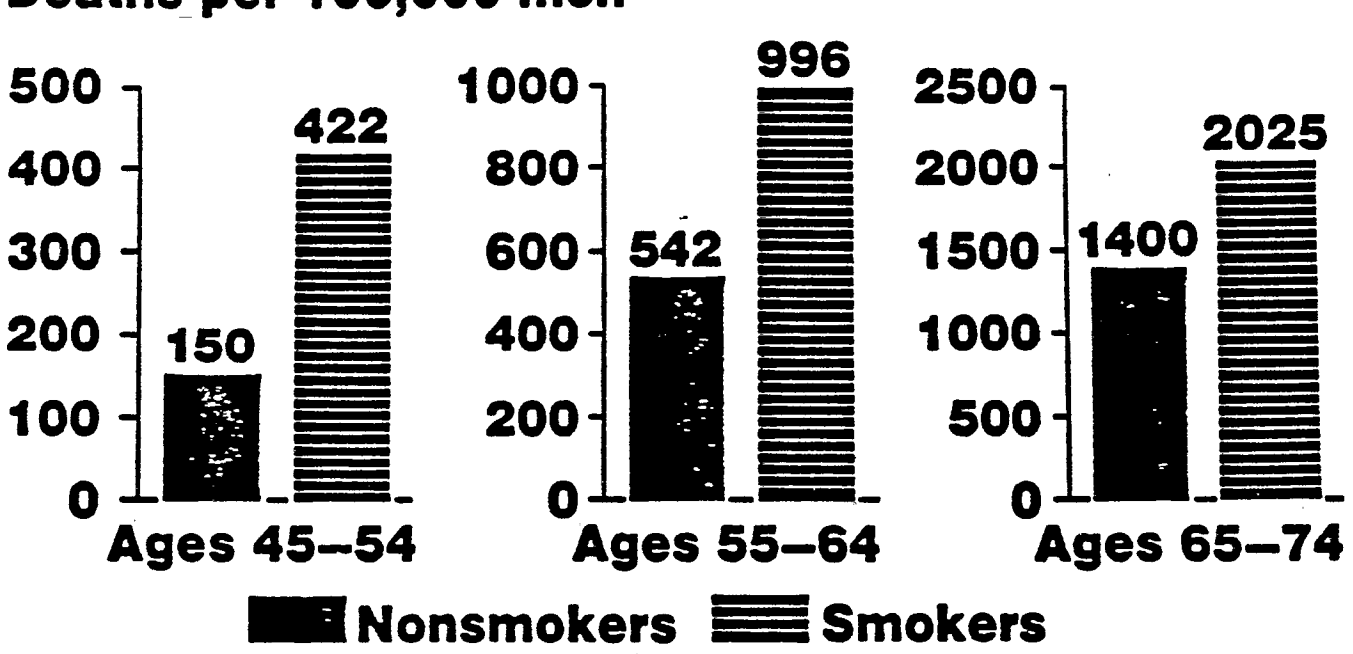
Major risk factor combinations, 10-year incidence of first major coronary events, men age 30-59 at entry, Pooling project



SM = smoker, C = cholesterol, H = hypertension

Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

Coronary heart disease deaths, smokers vs. nonsmokers



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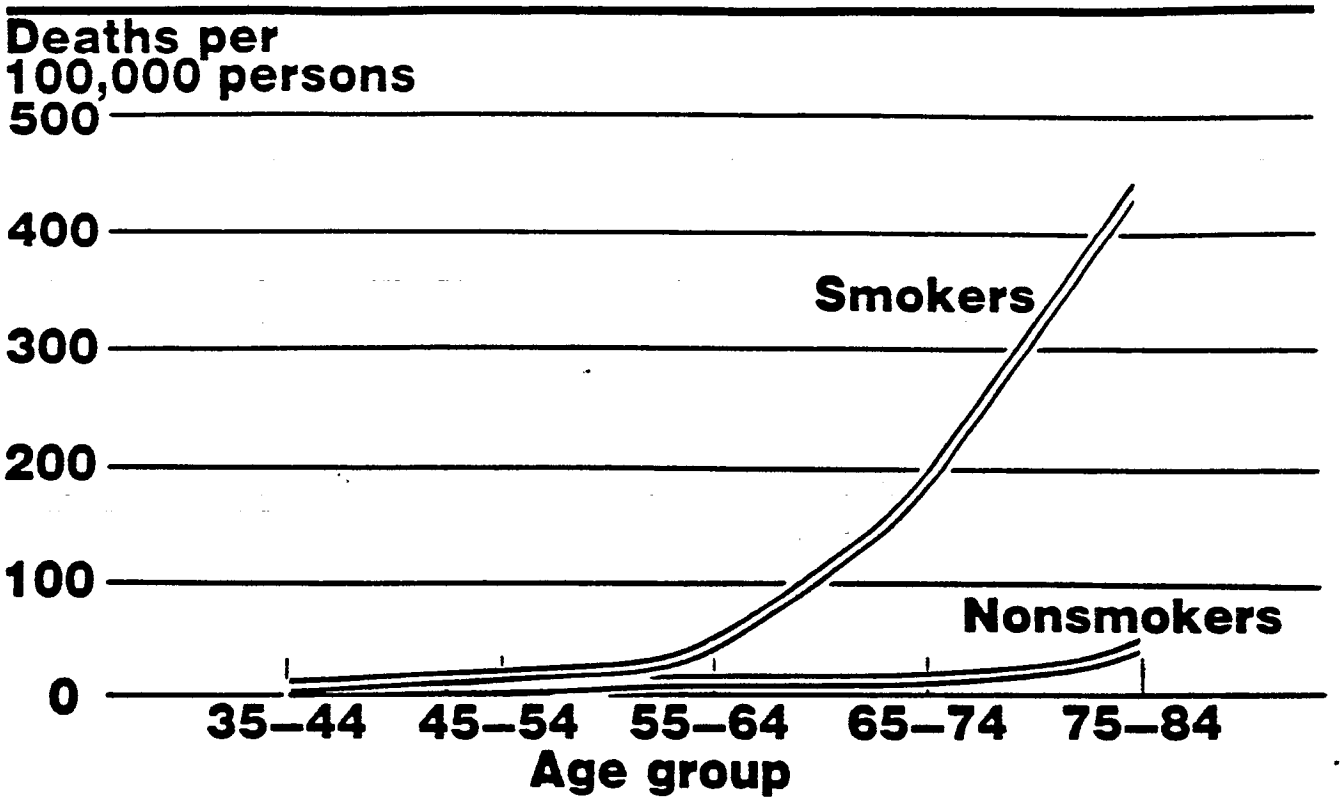
Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

COLD deaths smokers vs. nonsmokers



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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

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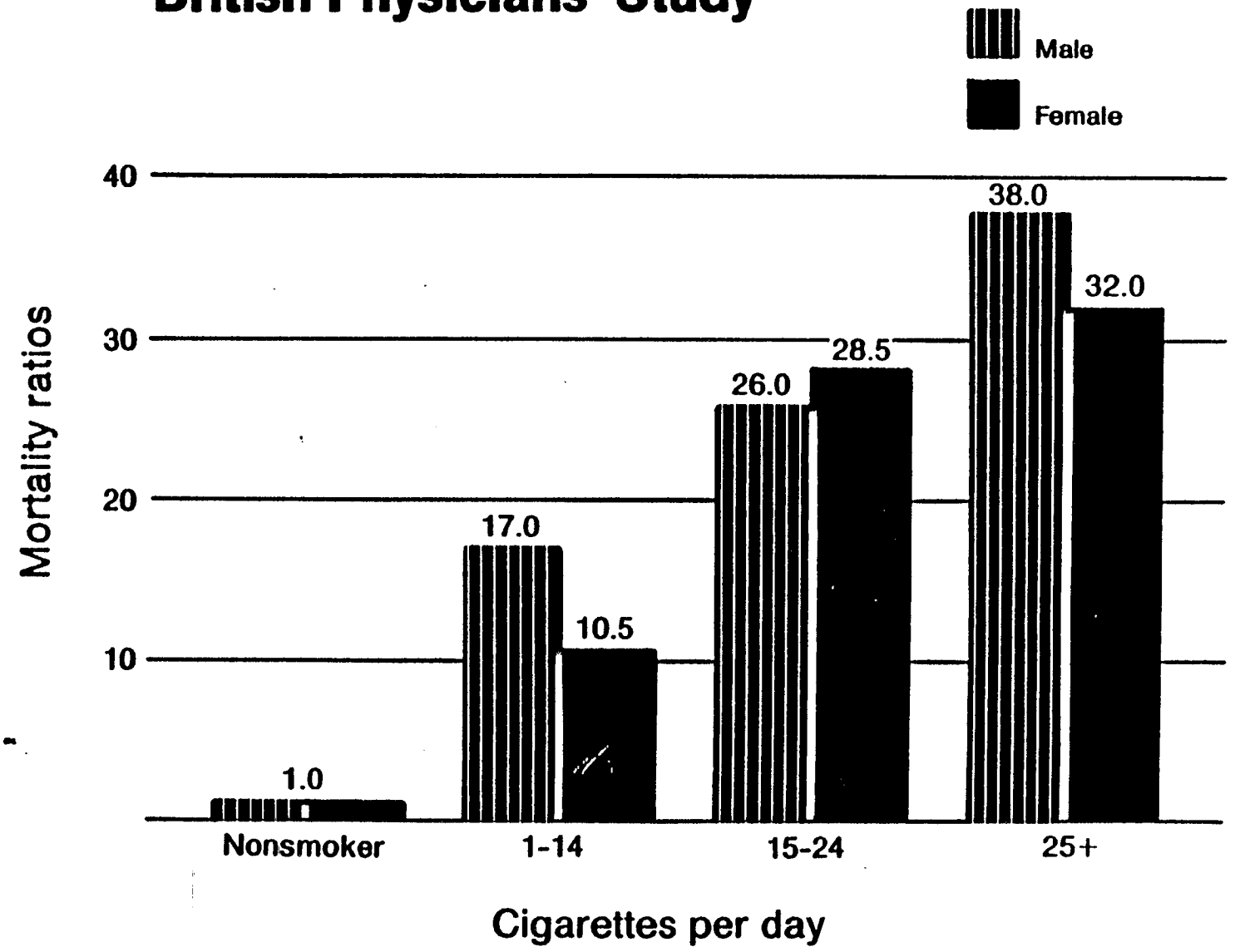
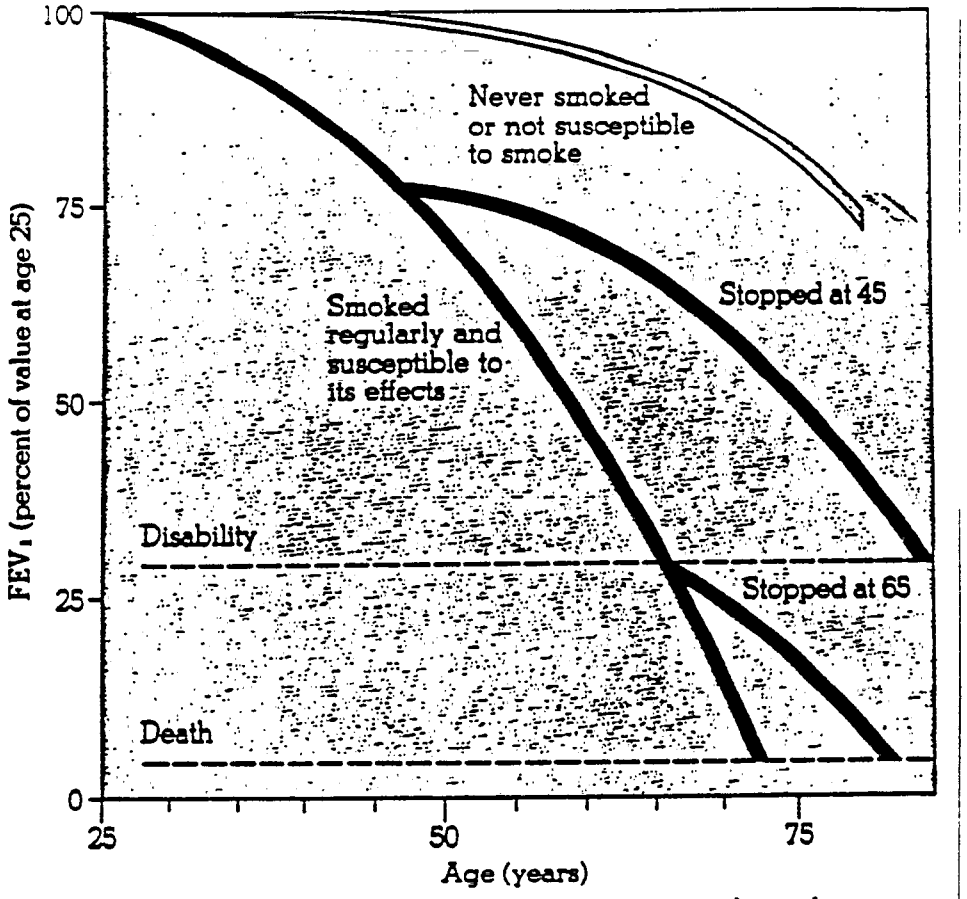
COLD mortality ratios for men and women, by number of cigarettes smoked per day, British Physicians' Study



Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

COPD Risk and Smoking Cessation



Risks for men with varying susceptibility to cigarette smoke and consequences of smoking cessation

Source: Fletcher, C.M., Peto, R: "The natural history of chronic airflow obstruction." *British Medical Journal* 1(6077):1645-1648, June 25, 1977.

Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

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field studies of particle mass concentrations associated with and smoking and nonsmoking occupancy.

Critical to the use of the short-term particle mass monitoring systems is a recognition of their relative accuracy in measuring ETS particle mass. Recently a detailed comparative study of the accuracy of the short-term measurement methods in measuring ETS RSP was reported (13). The study compared all of the MINIRAM, HAM and Piezobalance (Model 5000) to gravimetric mass measurements in a series of chamber studies where a wide range of chamber particle loadings were generated by tobacco combustion (machine generated sidestream, machine generated sidestream + mainstream and human smokers). The results of the study indicated that the piezobalances needed careful sample flow checks and calibration to agree with gravimetric measures. The MINIRAM after adjustment agreed well with gravimetric measures. The HAM was consistently low when compared to the gravimetric measure. The study suggests that while care must be taken in using the short-term measurement methods (calibration of flows, aerosol density corrections, etc.), such systems are very useful and surprisingly accurate in measuring particle mass associated with tobacco combustion.

MEASUREMENT METHODS FOR NICOTINE

Nicotine in ETS has recently been found to be predominantly in the vapor phase with on the order of less than 5% in the particle phase (14, 15, and 16). Active and passive sampling/analysis methods applicable to monitoring nicotine levels in occupied indoor environments have been developed and reported in the literature over the past four years. The methods are based upon the collection of nicotine by absorption on a sorbent resin or acidic surface with subsequent desorption and gas chromatography separation with a nitrogen-phosphorus detection (GC/NPD).

One active system (17,18) employs a personal sampling pump (typical industrial hygiene personal pump) to draw air at 1.0 1/min through a 7 mm glass tube containing XAD-4 sorbent. During sampling vapor phase nicotine is absorbed onto the XAD-4 sorbent, desorbed in the laboratory and analyzed by GC/NPD. The XAD-4 sorbent tubes can be purchased commercially. This method has been evaluated for sampling periods up to one hour with a lower detection limit of 0.1 ug/m3 and can be used as a personal or area monitor. This method has been used in both chamber and field studies of nicotine levels associated with ETS (19, 20).

The second active system (21) also uses a personal sampling pump to draw air at a rate of 1.7 1/min through a sampling cassette containing a particle filter and a filter treated with sodium bisulfate. The first filter collects the particles and second filter absorbs the vapor phase nicotine. The second filter is then desorbed and analyzed by GC/NPD. If particle

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phase nicotine is desired the first filter can be analyzed. The method has been evaluated for 8 hour sampling periods with a lower limit of detection of 0.2 ug/m3 and can be used as a personal or area monitor. The method has been used in both chamber and field studies of nicotine levels associated with ETS (21, 22). Using the same cassette method other investigators have proposed treating the second filter with chemicals other than sodium bisulfate for nicotine collection but the results have not yet been published in the open literature.

While not yet published small annular denuder systems for the measurement of nicotine in field studies of indoor spaces are being developed and evaluated (23). Denuder technology has been developed and used in chamber studies characterizing ETS and demonstrated applicable to indoor environmental measurements (24). Such systems will permit the measurement of vapor phase nicotine in indoor spaces at flow rates of about 1 1/min for periods up to several hours to a day or two. Further development of the denuders will be required before they can be used as personal monitors.

A passive monitor for measuring vapor phase nicotine in air has recently been reported (25). Passive sampling requires no pump and operates on the basis of molecular diffusion. Ideally, the sampling rate follows Fick's First Law of Diffusion and was determined, through a chamber study to sample at a rate of 24 ml/min. The passive monitor is a cassette which contains a filter treated with sodium bisulfate held in place by a Nuclepore windscreen. After sampling the treated filter is analyzed by GC/NPD. The passive cassette has been evaluated in chamber studies for 4-5 hours at a concentration as low as 16 ug/m3. The passive cassette can be used as a personal or area monitor for nicotine for a period of one or two days (depending on the concentration expected) to several weeks. Recently, the design of the passive cassette has been modified to utilize a new and more durable windscreen and to permit the easier handling and field use. Figure 1 shows the current design of the passive cassette. The passive cassette is currently being used as both a personal and area monitor in a number of field studies of nicotine levels associated with ETS.

A recently published report by the U.S. Environmental Protection Agency (26) provides a compendium on methods for nicotine sampling and analysis. The Compendium provides specific sampling and analysis procedures, in a standardized format, for the measurement of nicotine in air for the two active (XAD-4 and active cassette) methods and one passive (passive cassette) method discussed here.

SUMMARY

Assessing exposure to ETS can employee personal monitoring,

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biomarkers and modeling which utilized air monitoring of spaces, questionnaires and time activity patterns. Air monitoring is critical to assessing exposures to ETS in indoor environments and to assessing the effectiveness of efforts to control or mitigate exposures. ETS is a complex mix of several thousand chemicals found in both vapor and particle phase. The selection of a given air contaminant or class of contaminants to represent ETS for air monitoring purposes is at best complicated. No single contaminant or class of contaminants meet all the measures of and ideal ETS tracer or marker. Respirable suspended particle mass (RSP) and vapor phase nicotine are two reasonable markers for the ETS in indoor environments although not ideal. RSP and vapor phase nicotine measurements taken in an occupied space to assess ETS should take into account the spatial and temporal variations in those spaces and be complemented with some measure of smoking density and background air contaminant levels. A number of integrated and short-term measurement methods exist which can be used to measure vapor phase nicotine indoors. The choice of a given method is in large part determined by a purpose of the measurement and there financial and technical resources available.

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FIGURES AND TABLES FOR CHAPTER 5

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TABLE 1. Methods for Measuring RSP Indoors

Measurement Method	Sampling Times	Sampling Rates l/min	Concentration Range $\mu g/m^3$	Accuracy $\mu g/m^3$	Manufacturer	Cost $	Comments
A) Integrated Gravimetric with Cyclone or Impact or Size Selection							
1) Mass <3.5 μm cyclone	Hours/Days	~ 1.7	Lower limit varys by sampling time and concentration upper limit > mg/m^3	---	Pumps, cyclone separators and filters are sold by a number of manufacturers (Bendex, Gillan, etc.)	500-1,500	Sample collection and classical Industrial H niques System can be o or personal monitor
2) Mass 10-3 μm and < 3 μm Impactor	Hours/Days	5.5-6.5	Lower limit varys by sampling time and concentration upper limit > mg/m^3	---	National Bureau of Stds. under contract to US EPA US EPA Rsch. Tri. Pk.,NC 27711 (919) 541-7350	Unknown	Small self contained location sampling
3) Mass < 10 μm or < 2.6 μm	Hours/Days	4	Lower limit varys by sampling time and concentration upper limit > mg/m^3	---	Harvard Impactor Environmental Sciences Harvard Sch. of Pub. Hlth. 665 Huntington Ave. Boston, MA 02115 (617) 732-1000	2,500	Small self contained un location sampling. Ma controller for 14 day
B. Short-term Portable Methods							
1) Electrostatic Precp/ Piezoelectric Resonance < 3.5 μm	24 or 120 sec.	1	10-10,000	10 at 120 sec. sampling rate	Piezobalance (Model 3500) TSI Inc. PO Box 64394 St. Paul, MN 55164 (612) 483-0900	6,000	Changes in relative hum a measurement period ca Very portable
2) Forward Light Scattering 0.1-10.0 μm	Instant	Sampling by free convec.	10-100,000	50 at 10 sec. 20 at 60 sec. 6 at 600 sec.	GCA-MIni-RAM GCA Corp. 213 Burlington Rd. Bedford, MA 01730 (617) 275-5444	2,500	Maybe temperature sensi shouldn't be calibrated particulates. Is very
3) Forward Light Scattering 0.1-10 μm	Instant	1.5	10-10,000		HAM (Hand Held Aerosol Monitor) PPM, Inc. 11428 Kingston Pike Knoxville, TN 37922 (615) 966-8796	3,000-10,000	

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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

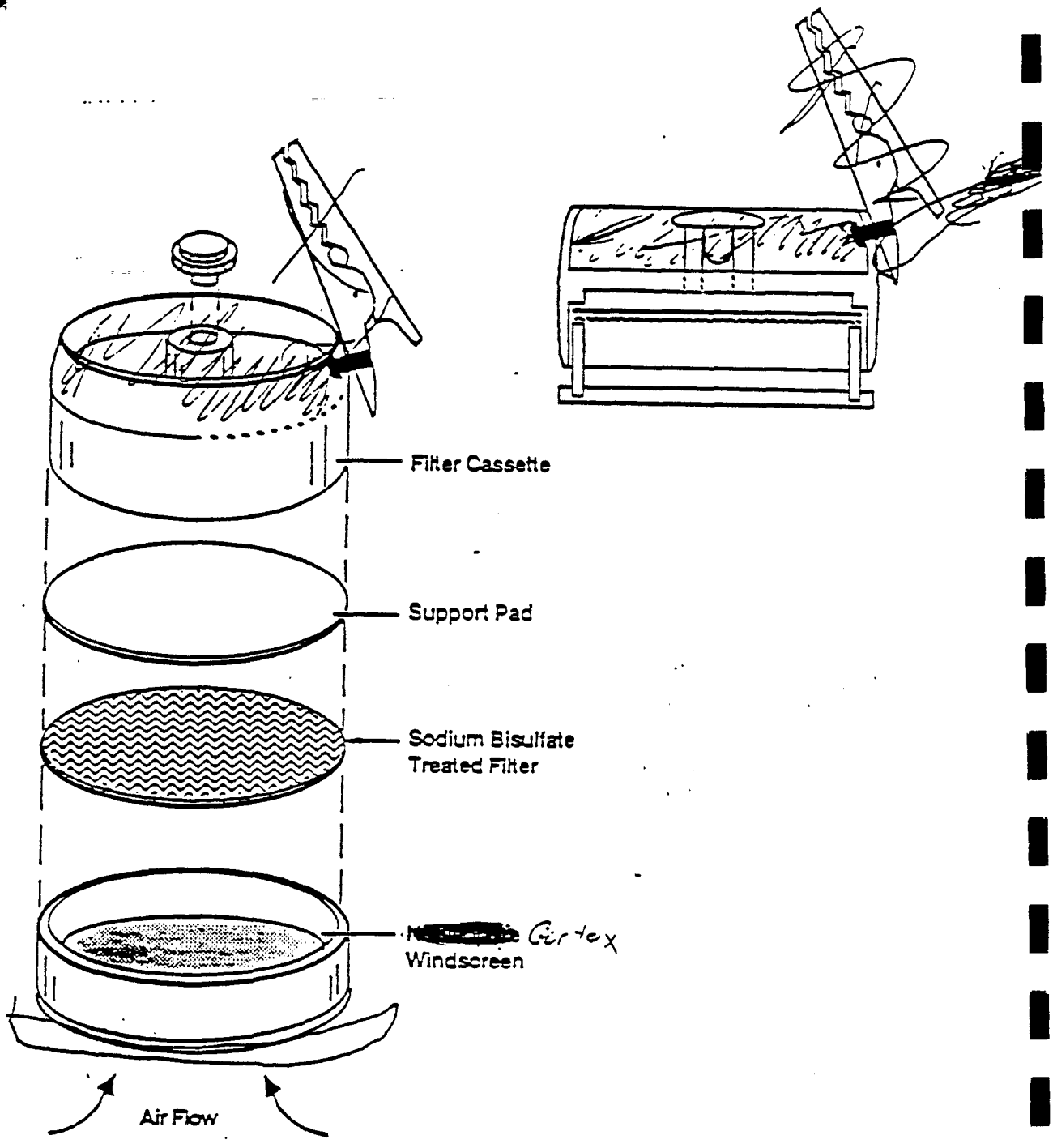

Figure 1

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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

CHAPTER 6

EXPOSURES TO AIR POLLUTANTS

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Harvard School of Public Health
Boston, Massachusetts

Microenvironments

Concentrations of air pollutants can and do vary depending on location. Outdoor pollutant levels may differ from indoor levels. Different indoor locations like homes, schools or workplace can also register varying pollutant levels. An individual's total exposure to air pollutants therefore depends on the time spent in each of these microenvironments and the various concentrations of air pollutants.

Time Activity Patterns

The amount of time a person spends in different microenvironments is influenced by age, sex, occupation, social class and season. Letz et al. (1984) studied the time-activity patterns of 332 residents of Roane county, Tennessee. The results of study showed that these individuals spent 75% of their time in the home. This was higher (84.9%) for housewives, unemployed and retired persons. The group spent 10.8% of the time at work with occupational groups working between 21-24% of their time. Of the remaining time: 8.5% was spent in public places, 9% in travel and 2.8% in various other locations.

Quakenboss et al. (1982) studied the time allocation for 66 family members from 19 homes in Portage, WI. Individuals were put into one of five general subgroups which are shown in Table 1. Despite wide variations, each group spent most of the time at home. For all participants. total time spent indoors was 85%.

More recently, Quakenboss and his colleagues analyzed time activity data for over 300 individuals in the Portage, WI area. Participants were categorized into three groups: workers, nonworkers, and students. Activity data were collected from both summer and winter seasons and are summarized in Table 2. Again all groups spent the largest percentage of their time in the home. Time spent outdoors decreased from summer to winter.

Infants, because they are essentially immobile, spend most of their time in the bedroom according to a recent study by Harlos

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et al. (1987). The rest of their time is usually spent in the livingroom, kitchen or in travel as illustrated in Figure 1.

There are some problems with determining total exposure based on time-activity patterns. It is not clear how well individual activity allocation can be generalized from overall population estimates or how concentration levels are affected by varying time and activity patterns. There also may be differences between rooms within microenvironments but this is not well understood.

Lebret (1985) examined the respirable suspended particulate (RSP) levels in rooms while participants were smoking or within one half hour of smoking. He found significant variation between the livingroom kitchen and bedroom. Ju and Spengler (1981), who studied 24-hour average concentrations of respirable particulates, also found statistically significant variation between some rooms although the absolute differences were relatively small.

Monitoring

There are a number of different instruments available to monitor air pollutants. Often the type of instrument used depends on the exposure of interest. Immediate exposures are most important when studying irritant and acute allergic responses. For this type of exposure, instruments which take short term or instantaneous readings are often used: the piezobalance or nephelometer are both used to measure particulates, the ecolyzer is used to measure carbon monoxide. One advantage to these types of instruments is their ability to detect peak pollutant levels.

For acute effects such a upper or lower respiratory infections, the exposures of interest range from hours to days. For increased prevalence of even a lifetime. To measure these exposures, integrated or time-averaging methods are used. These methods include filters which are used to collect particles over long time periods.

EXPOSURE TO AIRBORNE PARTICLES

Size Distribution and Composition of Particulates

The distribution of particulates is essentially trimodal with peak diameters at approximately 0.02 um, 0.5 um and 10 um as shown in Figure 2. The fine particle fraction, or <2.5 um, is produced by condensation. At least 75% of the sulfur, zinc, bromide and lead are found in this size range (Dzubay and Stevens, 1975). Particles <2.5 um are very important for health reasons since these particles can reach the alveolar regions on

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the lungs.

Particles greater than 2.5 um in diameter, or coarse particles, are usually formed by mechanical processes like grinding, crushing and abrasion. At least 75% of the silicon, calcium and iron, elements commonly found in soil, appear in this size fraction (Dzubay and Stevens, 1975). Particles from 2.5-10 um can be inhaled and can become deposited in the tracheobronchial regions.

Environmental Tobacco Smoke

Environmental tobacco smoke (ETS) is a mixture of exhaled mainstream smoke and sidestream smoke. Sidestream smoke is the smoke that is formed by smoldering between puffs, of a tobacco product and is the major source of ETS. The complex mixture that the smoker inhales with each puff of a cigarette, cigar or pipe is called mainstream smoke. The portion of mainstream smoke that the smoker inhales with each puff of a cigarette, cigar, or pipe is called mainstream smoke. The portion of mainstream smoke that the smoker exhales and the small amount of vapor diffusing through the wrapping of the cigar or cigarette add little to ETS.

ETS consists of fresh and aged sidestream and mainstream smoke. The particle sizes which make up ETS vary due to coagulation (the process where two or more particles collide and combine to form a larger particle), evaporation, and the adhesion of particles to surfaces. The size distribution of particles is also affected by air dilution, relative humidity and temperature.

Under controlled conditions, several researchers have measured the particle size distribution of sidestream smoke (Keith and Derrick, 1960; Porstendorger and Schraub, 1972; Hiller et al., 1982: Leaderer et al., 1984, Ingebrethsen and Sears, 1986). Based on these studies, the mass median diameter of sidestream smoke can be estimated to be between 0.2 um and 0.4 um. The mass median diameter is the diameter which divides the mass distribution in half, ie: one half of the mass is contributed by particles larger than this diameter and one half by particles smaller.

Composition of ETS

Environmental tobacco smoke is made up of several thousand different chemical compounds. These compounds may be in the gaseous or solid phase or both. The chemical composition of sidestream smoke differs from that of mainstream smoke. Over 2,000 compounds have been measured in sidestream and mainstream smoke. Some of the constituents in the mainstream smoke of nonfilter cigarettes are listed in Table 3. Also given are ratios of these substances in sidestream smoke compared to

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mainstream smoke. A ratio of greater than 1.0 means the constituent is found in higher concentrations in sidestream smoke than mainstream smoke. A number of the constituents listed are carcinogens or suspected carcinogens according to the International Agency for Research on Cancer.

Measurement of ETS

The large number of constituents in ETS make it impossible to assess overall exposure based on measurement of each one. Instead most researchers have measured one or more compounds and have used those to estimate the total exposure to ETS. Changes in ETS composition over time and exposure conditions limit the accuracy of this method.

This chapter will discuss in detail only a few of the possible measures of ETS: particles, nicotine, cadmium and nitrosamine. Most of the data presented will be from studies involving cigarette smoke since this is a major source of indoor ETS. Little work has been done on pipe or cigar smoke.

Exposures to Environmental Tobacco Smoke

According to the U.S. Department of Commerce (1985) about 30% of adults in the U.S. are smokers. 40% of homes nationwide have at least one smoker. In a survey of over 10,000 children in six U.S. cities, the percentage of children living with one or more smoking adults varied from a low of 60% to a high of 75% (Ferris et al,. 1979). Lebowitz and Burrows (1976) reported 54% of children in a study in Tucson had at least one smoker in the home. These data indicate that the potential for exposure to ETS in the home is greater than that inferred from national statistics.

Smoking between different demographic groups can vary widely and this will modify the exposure of nonsmokers to ETS. Overall ETS exposure will depend on the proximity of an individual to the source of smoke. Patterns of smoking will be influenced by time, location and type of activity.

MICROENVIRONMENTAL MEASUREMENTS OF CONCENTRATIONS

Concentrations of Particles and ETS

Numerous studies have been conducted using respirable suspended particulates (RSP) as markers for ETS. Both continuous and integrated measurements methods have been used. Although RSP is not specific for the presence of smokers in the home and other indoor locations, the number of cigarettes smoked have shown to correlate well with RSP.

Particulate Concentrations in Homes

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Spengler et al. (1981) measured 24-hour respirable particulate levels in 55 homes in six U.S. Cities. The mean monthly concentration across cities is presented in Figure 3 with indoor particulate levels are similar to the outdoor levels. Table 4 shows the respirable particulate levels in the homes as a function of the number of smokers. The actual amount of smoking in the home was not reported. The researchers concluded that the major source of indoor particulates in smoking homes was cigarette smoke. Each smoker in the home raised the mean respirable particulate level by 20 μg/m3.

Further analysis of the data by Dockery and Spengler (1981) showed that each cigarette smoked in the home increased the mean respirable particulate levels by 0.88 μg/m3. In air conditioned homes, the respirable particulate levels increased by 2.11 μg/m3 per cigarette per day. This increase was probably caused by recirculation of indoor air which reduced the cigarette smoke dilution.

More recently Spengler and colleagues (1986) analyzed RSP data from over 200 homes in Watertown, MA. Homes with smokers had RSP concentrations of 30 to 35 μg/m3 higher than nonsmoking homes. RSP concentration and the number of cigarettes smoked per week were highly correlated. Models based on this data predict a contribution of 0.77 μg/m3 per cigarette per day. This would mean a pack of cigarettes would increase the indoor RSP concentration by 15.5 μg/m3.

McCarthy et al. (1987) placed fixed monitors in homes for two consecutive 24 hour sampling periods. The RSP measurement was highly correlated with the consumption of cigarettes in the home. The indoor RSP values for smoking households were consistently higher than those for nonsmoking homes to 56 μg/m3 in smoking homes.

Particulate Concentration in Offices

Using a piezobalance, Weber and Fischer (1980) monitored 44 workrooms at seven different companies in Switzerland. The workrooms had varying levels of smoking. A number of samples were taken in each room over a two day period. After subtracting the particulate levels found in an unoccupied room, the mean particulate level for the 492 samples taken was 133 μg/m3 with a standard deviation of 130 μg/m3. The maximum concentration measured was 962 μg/m3.

Quant et al. (1982) used a piezobalance, to monitor three offices. The offices were divided into cubicles with half-wall partitions and contained both smoking and nonsmoking areas. Offices were monitored continuously for one work week. Figure 4 shows the results of continuous monitoring in one of the offices. For the three offices, the ten hour day averages ranged from 37μg/m3 to 89 μg/m3.

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Miesner et al. (1988) used both continuous and integrated methods to monitor in five office buildings in metropolitan Boston. Both filters and nephelometer were used to measure in 12 offices, one conference room and a designated smoking room of a large nonsmoking office to 1200 μg/m3 in the designated smoking room. Short-term nephelometer readings ranged from zero in a nonsmoking office to 1200 μg/m3 in the same smoking room mentioned above.

Particulate Concentration in Offices

Repace and Lowry (1980) measured particulate levels in various indoor public facilities both in the absence and presence of smoking. For nonsmoking locations such as restaurants, libraries, a church, and a bakery, the mean indoor RSP level was less than 60 μg/m3. Measurements taken in public facilities in the presence of smoking are shown on Table 5. Measurements range from 86μg/m3 for an eight minute measurement in a sandwich restaurant by other researchers using continuous monitoring methods to measure particulate levels in public facilities are presented in Table 6.

Besides monitoring in offices, Miesner et al. (1988) also took continuous and integrated RSP measurements in numerous public facilities including: a library, museum, school, subway, bars and restaurants. They found that for most public buildings where no smoking was present the particulate levels were low, usually less than 30 μg/m3. Levels in transportation facilities such as the subway and bus stations were slightly higher with a mean integrated measurement of 63 μg/m3. Higher concentrations were found in smoking areas such as bars, restaurants and a public smoking room with a mean integrated measurement of 79 μg/m3 and a standard deviation of 44 μg/m3.

Concentration of Other Components of ETS

Numerous researchers have looked at other tracers for ETS. Because of its high specificity for tobacco smoke and its presence in high concentration nicotine is a promising choice. McCarthy et al. (1987) also measured indoor nicotine levels in smoking and nonsmoking homes. The home nicotine values ranged from an average of 0.1 μg/m3 in the nonsmoking households to 4.2 μg/m3 in the smoking households. The presence of low nicotine values in some of the nonsmoking households can be accounted for by visitors to the home who were smokers.

A number of studies have used integrated readings to determine nicotine levels in offices and public buildings. A selection of these studies are presented in Table 7.

Cigarettes are also known to be a source of cadmium. Lebret

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et al. (1987) considered cadmium as a useful tracer for ETS. They monitored twenty homes and one outdoor site for fine particulates in Watertown, MA. Particles were analyzed for elemental composition using x-ray fluorescence. At the outdoor site and in homes without smokers, cadmium levels were below the detectable limit. Indoor cadmium levels were below the detectable limit. Indoor cadmium levels were highly correlated with indoor fine particulate measurements.

Nitrosamines, some of which have been listed as animal carcinogens by the International Agency for Research on Cencer, have been studied in public facilities and homes (Brunnemann et al., 1978). Using continuous measurements they found mean levels of nitrosamines in public facilities which ranged from 0.01 to 0.24 ng/L. Both homes monitored had levels of less than 0.0005 ng/L.

Wallace et al. (1987) measured the personal exposure and breath levels of benzene and other aromatics in 200 smokers and 322 nonsmokers in New Jersey and California. Benzene is listed as a human carcinogen by the IARC (1986). They found a significant increase in breath concentration with the number of cigarettes smoked. Smokers were found to have up to 10 times the breath concentration of benzene compared to nonsmokers. Nonsmokers who reported smoke exposure at work showed elevated levels for fall and winter but not for spring and summer. The authors concluded that cigarettes were the major source of benzene for about 50 million U.S. smokers.

No single constituent of ETS is sufficient to completely characterize an individuals exposure to ETS. Research on ways to relate these measurements to specific health effects continues to be done. The most prudent course is to measure several of these components in exposure studies. Markers specific to the class of ETS components, or health outcome of interest could be utilized in epidemiologic studies to enhance precision of the exposure.

Personal Exposures.

Personal monitoring studies have many of the same problems that area monitoring has such as trying to measure ETS exposure based on one or more markers. However, personal exposure monitoring has the advantage of including spatial and temporal dimensions to the measurements. It is also possible to use time activity diaries to link exposure with location and activity.

The results of a personal monitoring study by McCarthy et al. (1987) show that the exposure of children to RSP was much higher than that of children from nonsmoking households. The average personal RSP value increased from 29 $\mu g/m3$ for children from nonsmoking families to 56 $\mu g/m3$ for children from smoking families. The average personal nicotine concentration increased

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from 0,3 µg/m3 to 2.5µg/m3 for children from nonsmoking and smoking families respectively. A child's personal nicotine is highly correlated with the consumption of cigarettes in the home while the personal RSP was not. This implies that although there are multiple sources of RSP, the majority of ETS exposure is from the child's home.

Spengler et al. (1985) had 101 nonsmoking volunteers from Kingston/Harriman, Tennessee wear personal respirable suspended particulate monitors for 3 days. Nonsmokers were divided in two groups: those who lived with a smoker and those who did not. Outdoor and indoor particulate levels were taken for comparison. Results showed that personal exposure was not correlated with outdoor concentrations but that ETS significantly increased an individuals personal concentration profile.

In Spengler and Tosteson (1981) 45 nonsmoking adults were monitored for RSP for 18 days. They were also divided into two groups: those exposed to ETS and those who were not. Area monitors were also placed inside and outside. Personal exposure was higher than both indoor and outdoor measurements. On average the individual exposure was increased by 20 µg/m3 among those who reported exposure to ETS.

Cotinine is a major metabolite of nicotine. McCarthy et al (1987) measured cotinine levels in the urine and saliva of 81 nonsmoking children. Nicotine levels in the air were also monitored as was RSP. They found a high correlation between personal nicotine levels and cotinine indicating a quantitative relationship may exist. They did however, find high variability.

Coultas et al. (1987) measured cotinine in the saliva of 1360 nonsmoking children and adults. They found an increase with the number of smokers in the home at all ages. However, household variability was wide and even 30% of the nonsmokers living in a no smoking home had detectable cotinine levels.

Summary

1. Environmental tobacco smoke is the primary contaminant causing elevated RSP levels in enclosed spaces.

2. Environmental tobacco smoke can be a substantial contributor to the level of indoor air pollution concentration of benzene, acrolein, N-nitrosamine, pyrene and carbon monoxide.

3. Measured exposures to respirable suspended particulates are higher for nonsmokers who report exposure to ETS.

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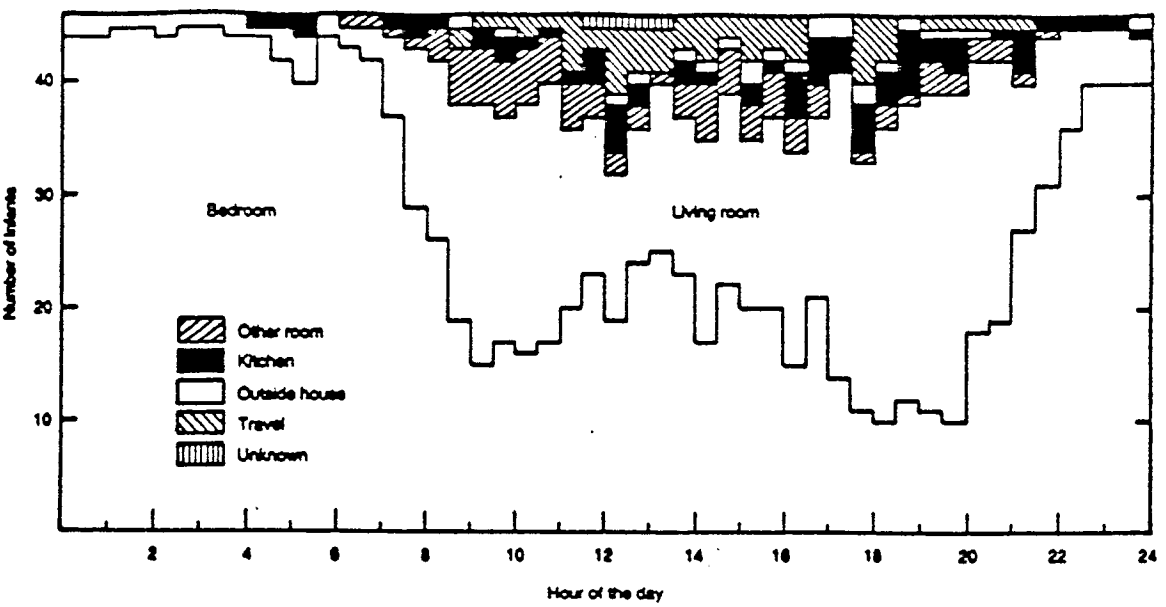

FIGURE 1. -Time Location Patterns for 46 Infants

Source: Harlos et al. (1987)

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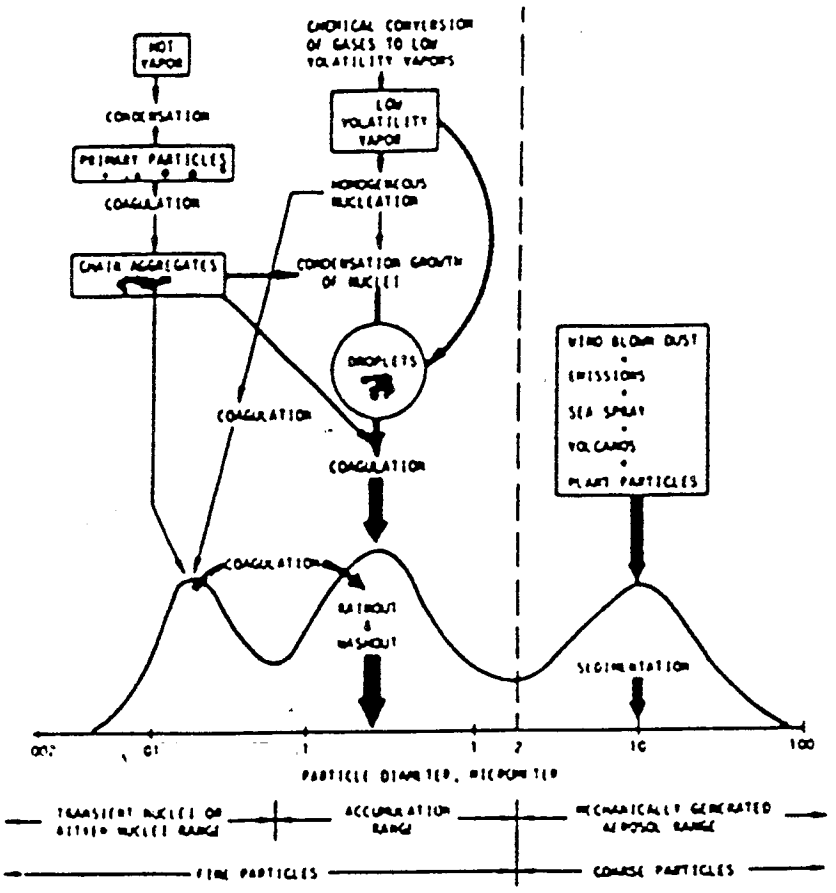

FIGURE 2. Schematic of an Atmospheric Aerosol Surface Area Distribution Showing the Three Modes, Main Source of Mass for Each Mode, the Principal Process Involved in Insetting Mass into Each Mode, and the Principal Removal Mechanisms

Source: Whitby (1978)

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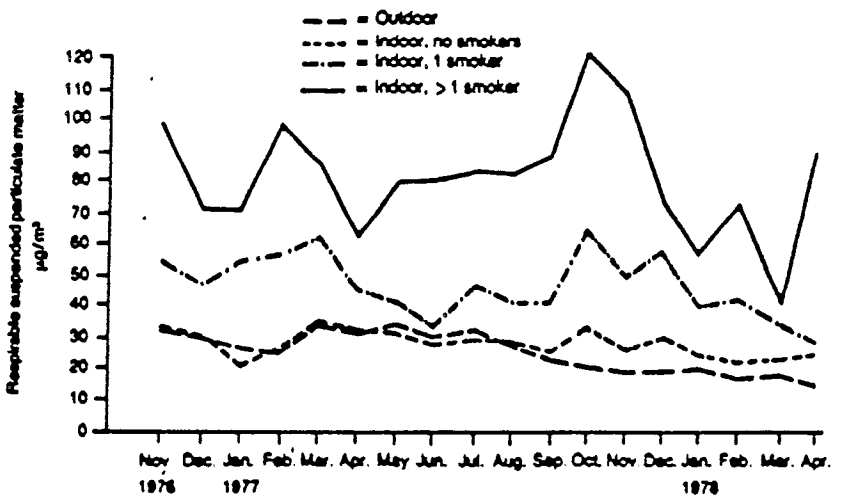

FIGURE 3. Monthly Mean Mass Respirable Particulate Concentrations ($\mu g/m^3$) Across Six Cities

Source: Spengler et al. (1981)

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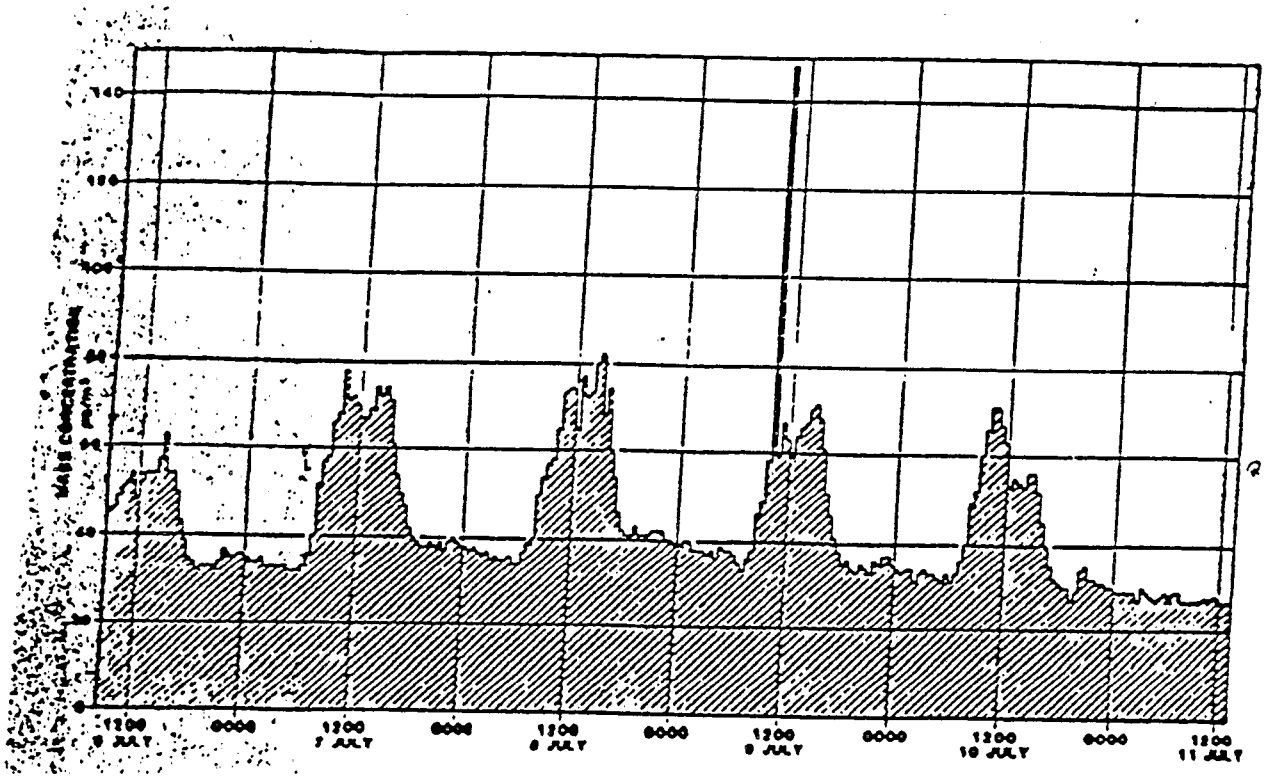

FIGURE 4. Aerosol Mass Concentration in R & D Office

Source: Quant et al. (1982)

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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

TABLE 1. Mean Percent and Standard Deviation of Time Allocation in Various Locations by Work or School Classification Subgroup

Location	Homemaker	Student	Outdoor worker	Office/ Service	Industrial/ Construction	Total, all participants
Home	84.34 (2.02)[1]	60.91 (13.92)	49.97 (12.24)	68.74 (8.72)	57.28 (7.05)	64.21 (13.99)
Outside	5.52 (3.27)	8.62 (5.53)	19.81 (8.55)	2.47 (2.49)	10.59 (10.74)	8.08 (7.07)
Motor vehicle	4.28 (3.19)	5.11 (3.74)	8.67 (6.15)	4.69 (2.33)	7.64 (7.52)	5.51 (4.29)
Other indoors	6.01 (3.27)	23.61 (10.61)	21.55 (5.32)	24.99 (10.24)	24.80 (12.86)	21.58 (11.37)
Cooking	4.69 (1.88)	0.34 (0.79)	0.00 (0.00)	2.32 (2.30)	0.52 (0.86)	1.24 (1.96)
Near smokers	2.84 (4.32)	5.20 (7.88)	2.75 (3.38)	11.73 (15.19)	12.03 (10.05)	6.89 (9.71)
Number	8	32	4	12	8	66[2]

[1] Numbers in parentheses are the standard deviation.
[2] Two unemployed participants were included in the total, but not given a separate category.
SOURCE: Data from Quackenbos et al. (1982).

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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

TABLE 2. Mean Percent Time Spent in Various Locations for Three Population Groups

phase	location	population group			combined totals
		workers	nonworkers	students	
summer	home (SD)	59.3 (11.9)	75.2 (12.1)	68.3 (12.5)	65.4 (13.3)
	outside (SD)	12.3 (9.1)	12.9 (9.9)	15.0 (9.3)	13.7 (9.4)
	motor vehicle (SD)	5.8 (4.2)	4.4 (2.7)	3.3 (4.3)	4.4 (4.3)
	work/school (SD)	15.5 (10.9)	0.2 (0.8)	4.4 (7.8)	8.4 (10.6)
	other indoors (SD)	7.0 (6.4)	7.2 (6.4)	9.0 (9.6)	8.1 (8.2)
	N	137	32	177	346
winter	home (SD)	66.1 (11.4)	83.3 (8.4)	66.1 (10.1)	67.5 (11.5)
	outside (SD)	3.3 (5.35)	1.9 (2.0)	3.9 (3.3)	3.5 (4.2)
	motor vehicle (SD)	5.6 (5.6)	4.3 (2.5)	3.3 (2.6)	4.2 (4.1)
	work/school (SD)	18.6 (10.4)	3.0 (7.1)	19.5 (7.5)	17.9 (9.7)
	other indoors (SD)	6.4 (6.0)	7.6 (5.3)	7.3 (6.2)	7.0 (6.1)
	N	127	26	176	329

Source: Quackenboss et al. (1986)

204022544 2

Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

TABLE 3. Distribution of Constituents in Mainstream Smole (MS) and the Ratio of Sidestream Smolke (SS) to MS of Nonfilter Cigarettes

Vapor phase constituents[1]	MS range	SS/MS ratio	Particulate phase constituents[1]	MS range	SS/MS ratio
Carbon monoxide	10–23 mg	2.5–4.7	Particulate matter[1]	15–40 mg	1.3–1.9
Carbon dioxide	20–40 mg	8–11	Nicotine	1–2.5 mg	2.6–3.3
Carbonyl sulfide	18–42 µg	0.03–0.13	Anatabine	2–20 µg	<0.1–0.5
Benzene[1]	12–48 µg	10	Phenol	60–140 µg	1.6–3.0
Toluene	160 µg	6	Catechol	100–360 µg	0.6–0.9
Formaldehyde	70–100 µg	0.1–a50	Hydroquinone	110–300 µg	0.7–0.9
Acrolein	60–100 µg	8–15	Aniline	360 ng	30
Acetone	100–250 µg	2–5	2-Toluidine	160 ng	19
Pyridine	16–40 µg	6.5–20	2-Naphthylamine[2]	1.7 ng	30
3-Methylpyridine	12–36 µg	3–13	4-Aminobiphenyl[2]	4.6 ng	31
3-Vinylpyridine	11–30 µg	20–40	Benz[a]anthracene[4]	20–70 ng	2–4
Hydrogen cyanide	400–500 µg	0.1–0 25	Benzo(a)pyrene[3]	20–40 ng	2.5–3.5
Hydrazine[3]	32 ng	3	Cholesterol	22 µg	0.9
Ammonia	50–130 µg	40–170	γ-Butyrolactone[4]	10–22 µg	3.6–5.0
Methylamine	11.5–28.7 µg	4.2–6.4	Quinoline [4]	0.5–2 µg	8–11
Dimethylamine	7.8–10 µg	3.7–5.1	Harman	1.7–3.1 µg	0.7–1.7
Nitrogen oxide	100–600 µg	4–10	N'-Nitrosonornicotine[4]	200–3,000 ng	0.5–3
N-Nitrosodimethylamine[4]	10–40 ng	20–100	NNK[4]	100–1,000 ng	1–4
N-Nitrosopyrrolidine[4]	6–30 ng	6–30	N-Nitrosodienthanolamine[4]	20–70 ng	1.2
Formic acid	210–490 µg	1.4–1.6	Cadmium	100 ng	7.2
Acetic acid	330–810 µg	1.9–3.6	Nickel[3]	20–80 ng	13–30
			Zinc	80 ng	6.7
			Polonium-210[3]	0.04–0.1 pCi	1.0–4.0
			Benzoic acid	14–28 µg	0.67–0.96
			Lactic acid	63–174 µg	0.5–0.7
			Glycolic acid	37–126 µg	0.6–0.96
			Succinic acid	110–140 µg	0.43–0.62

[1] Values are given for fresh and undiluted MS and SS.
[2] Human carcinogen (IARC 1986).
[3] Suspected human carcinogen (IARC 1986).
[4] Animal carcinogen (IARC 1986).

SOURCE: Elliott and Rowe (1975); Hoffmann et al. (1983); Klus and Kuhn (1982); Sakuma et al. (1983); Sakuma, Kusama, Yamaguchi, Matsuki et al. (1984); Sakuma, Kusama, Yamaguchi, Sugawara (1984); Schmeltz et al. (1975).

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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

TABLE 4. Respirable Particulate Levels as a Function of Number of Smokers

Smoker status	Number	Mean (μg/m³)	Standard deviation
No smokers	35 homes/1,186 samples	24.4	11.6
1 smoker	15 homes/494 samples	36.5	14.5
2 smokers	5 homes/163 samples	70.4	42.9
2+ smokers	4 homes/7 samples	51.8	12.3

SOURCE: Spengler et al. (1981).

2040225444

Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

TABLE 5. Particulates Measured under Realistic Conditions

Study	Type of premises	Occupancy (active smokers per 100 m^3)	Ventilation	Monitoring conditions (min)	Levels ($\mu g/m^3$) Mean	SD	Nonsmoking controls ($\mu g/m^3$) Mean	SD
Repace and Lowrey (1980)	Cocktail party	0.75	Natural	15	351	± 38	24	
	Lodge hall	1.26	Mechanical	50	697	± 28	60[1]	
	Bar and grill	1.78	Mechanical	18	589	± 28	63[1]	
	Firehouse bingo	2.77	Mechanical	16	417	± 63	51[1]	
	Pizzeria	2.94	Mechanical	32	414	± 58	40[1]	
	Bar/cocktail lounge	3.24	Mechanical	26	334	± 120	50[1]	
	Church bingo game	0.47	Mechanical	42	279	± 18	30	
	Inn	0.74	Mechanical	12	239	± 9	22[1]	
	Bowling alley	1.53	Mechanical	20	202	± 19	49[1]	
	Hospital waiting room	2.15	Mechanical	12	187	± 52	58[1]	
	Shopping plaza restaurant							
	Sample 1	0.18	Mechanical	18	153	± 8	59[1]	
	Sample 2	0.18	Mechanical	18	163	± 4	36[1]	
	Barbeque restaurant	0.89	Mechanical	10	136	± 17	40[1]	
	Sandwich restaurant A							
	Smoking section	0.29	Mechanical	20	110	± 36	40[1]	
	Nonsmoking section	0	Mechanical	20	55	± 6	30	
	Fast-food restaurant	0.42	Mechanical	40	109	± 38	34[1]	
	Sports arena	0.09[2]	Mechanical	12	94	± 13	55[1]	
	Neighborhood restaurant/bar	0.40	Mechanical	12	93	± 17	55[1]	
	Hotel bar	0.59	Mechanical	12	93	± 2	30	
	Sandwich restaurant B							
	Smoking section	0.13	Mechanical	8	86	± 7	55	
	Nonsmoking section	0	Mechanical	21	51			
	Roadside restaurant	1.12	Mechanical (9.5 ach^3)	18	107[4]		30	
	Conference room	3.54	Mechanical (4.3 ach^3)	6	1947[4]		55	
Repace and Lowrey (1982)	Dinner theater	0.14	Mechanical	44	145	± 43	47	± 10
	Reception hall	1.19	Mechanical	20	301	± 30	28[1]	
	Bingo hall	0.83[2]	Natural	2	1140		40[1]	
		0.83[2]	Mechanical (1.39 ach^3)	6	443[4]		40[1]	

[1] Sequential outdoor measurement (5 minute average).
[2] Estimated.
[3] Air changes per hour.
[4] Equilibrium level as determined from concentration vs. time curve.

SOURCE: U.S. Department of Health and Human Services (1986)

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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000

TABLE 6. Nicotine Measured Under Realistic Conditions

Study	Type of premises	Occupancy	Ventilation	Monitoring conditions	Levels (μg/m³) Mean	Levels (μg/m³) Range	Nonsmoking controls Mean	Nonsmoking controls Range
Badre et al. (1978)	6 cafes	Varied	Not given	60 min sample		25–52		
	Room	18 smokers	Not given	60 min sample	500			
	Hospital lobby	12 to 30 smokers	Not given	60 min sample	37			
	2 train compartments	2 to 3 smokers	Not given	60 min sample		36–50		
	Car	3 smokers	Natural, open	60 min sample	65			
			Natural, closed	60 min sample	1010			
Cano et al. (1970)	Submarines 66 m³	157 cigarettes per day	Yes		32 μg/m³			
		94–103 cigarettes per day	Yes		15–35 μg/m³			
Harmsen and Effenberger (1967)	Train	Not given	Natural, closed	30–45 min samples		0.7–3.1		
Hinds and First (1975)[1]	Train	Not given	Not given	2½ hr samples	4.9		Values not given	
	Bus	Not given	Not given	2½ hr samples	6.3		Values not given	
	Bus waiting room	Not given	Not given	2½ hr samples	1.0		Values not given	
	Airline waiting room	Not given	Not given	2½ hr samples	3.1		Values not given	
	Restaurant	Not given	Not given	2½ hr samples	5.2		Values not given	
	Cocktail lounge	Not given	Not given	2½ hr samples	10.3		Values not given	
	Student lounge	Not given	Not given	2½ hr samples	2.8		Values not given	
Weber and Fischer (1980)[2]	44 offices	Varied	Varied	140 × 3 hr samples	0.9 ± 1.9	13.8 (peak)	Values not given	
First (1984)	1 public building	Nonsmokers	Mechanical	Not given			5.5	
	8 public buildings	1 to 5 smokers	Natural and mechanical	Not given	13.2	2.7–30.0		
Muramatsu et al. (1984)	Office	Not given	Not given	Not given	19.4	9.3–31.6		
	Office	Not given	Not given	Not given	22.1	14.6–28.1		
	Laboratory	Not given	Not given	Not given	5.8	1.8–9.6		
	5 conference rooms	Not given	Not given	Not given	38.7	16.5–53.0		
	3 houses	Not given	Not given	Not given	11.1	7.8–14.6		
	Hospital lobby	Not given	Not given	Not given	3.0	1.9–5.0		
	4 hotel lobbies	Not given	Not given	Not given	11.2	5.5–18.1		
	5 restaurants	Not given	Not given	Not given	14.8	7.1–27.8		
	3 cafeterias	Not given	Not given	Not given	28.4	11.6–42.2		
	3 bus and railway waiting rooms	Not given	Not given	Not given	19.1	10.1–36.4		
	4 cars	Not given	Not given	Not given	47.7	7.7–83.1		
	8 trains	Not given	Not given	Not given	16.4	8.6–28.1		
	7 airplanes	Not given	Not given	Not given	15.2	6.3–28.8		

[1] Background levels have been subtracted.

[2] Control values (unoccupied rooms) have been subtracted.

SOURCE: U.S. Department of Health and Human Services (1986)

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Source: https://www.industrydocuments.ucsf.edu/docs/xtdl0000